NEW
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500 PLAIN ANSWERS TO DIRECT QUESTIONS

ON

STEAM, HOT WATER, VAPOR *and* VACUUM HEATING

THE SCIENCE AND PRACTICE OF HEATING EXPLAINED IN A SERIES OF PLAIN QUESTIONS AND ANSWERS, WITH TABLES, RULES AND GENERAL INFORMATION, FORMING A COMPLETE TEXT BOOK AND MANUAL. A HELP TO THE APPRENTICE AND JOURNEYMAN STEAM FITTER IN PREPARING FOR EXAMINATION. A REFERENCE BOOK FOR MASTER STEAM FITTERS, ARCHITECTS AND HEATING CONTRACTORS.

BY

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PREFACE

The rapid advancement in methods of heating and ventilation compel the progressive steam fitter to read and study constantly in order to keep abreast of the times and in touch with the latest improvements. Systems of heating are now in almost common use which were unheard of three, five or ten years ago.

Text books and manuals on the subject of heating written a few years ago are no longer up-to-date and are now of benefit to the steam fitter only as books of reference, descriptive of the history of heating up to the time of their publication, and giving rules, tables and formulas for reference.

This work—in the form of brief questions and answers—is intended as a guide and text book for the younger, inexperienced fitter, and as a reference book for all fitters. All long and tedious discussions and descriptions formerly considered so important have been eliminated, and the theory and laws of heat and the various old and modern methods and appliances used for heating and ventilating are treated in a brief and concise manner. A sufficient number of illustrations, rules and tables are included to make the book complete for handy and ready reference.

A. G. KING.

February, 1915.

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THE THEORY AND LAWS OF HEAT.

1. **Q. What is heat?**

A. Heat is a form of energy or motion produced by friction. All matter is made up of small rapidly vibrating particles or molecules. The faster these particles vibrate the more heat is produced and the more the body is expanded. This expansion is often carried to such an extent as to transform the body into another state.

2. **Q. Give an example of a change in the form of a body due to heat.**

A. The formation of steam from water.

3. **Q. How is heat measured?**

A. By the effect it produces. As heat is not a substance it cannot be measured by the foot or bushel, nor can it be weighed by the pound. It is calculated by the effect it produces upon another body to which it is transferred.

4. **Q. How is heat transferred from one body to another?**

A. By conduction, convection and by radiation.

5. **Q. Give examples of heat transferred by each of these methods.**

A. The heat from a hot iron is transferred to another piece of iron by contact with it, as when one end is placed in the fire the opposite end becomes warm. This is transference by conduction. Water heated at the boiler and delivered to a radiator by means of currents makes the radiator hot. This is heating by convection. An object located near a stove or radiator is made warm by the heat diffused and transferred to it by the stove or radiator. This is heat transference by radiation.

6. **Q. How is the effect of heat transferred from one body to another measured?**

A. By the Heat Unit.

7. **Q. What is a Heat Unit?**

A. A heat unit is a scale for measuring the effect of heat, and all heating calculations are based on and measured by the heat unit. There are three standards of measure: British, French and German.

8. **Q. Which of these measures is in general use in this country?**

A. That which is known among heating men and engineers

as the British Thermal Unit (B. T. U.). This is the unit employed in all American and British practice.

9. Q. **What is the measure of a British Thermal Unit?**

A. A British Thermal Unit (B. T. U.) is the amount of heat required to raise one pound of water from 32 degrees to 33 degrees on the Fahrenheit scale. This amount is measurable and always the same, as would be one inch for length or one pound for weight.

10. Q. **What is meant by the Fahrenheit scale?**

A. Fahrenheit was a German who in 1724 invented the thermometer and scale which are used in the United States and Great Britain and British Colonies; the scale ranging from Zero (0) to 212 degrees, the boiling point, 32 degrees being the freezing point.

11. Q. **What is the mechanical equivalent of heat or the mechanical effect produced by its application?**

A. One unit of heat is capable of raising 772 pounds weight one foot high. This is termed "foot pounds." J. P. Jule, while experimenting (1838), determined or discovered a definite relationship between heat and work.

12. Q. **What is meant by equalizing heat between two bodies?**

A. When a difference in temperature exists between two bodies, solid or liquid, that come in contact with each other it is a law of heat that their temperature will become equalized. There is always a tendency for heat to flow from a hotter to a colder body.

13. Q. **Give an example of the operation of this law?**

A. Pour a gallon of water having a temperature of 50 degrees into a vessel containing a gallon of water having a temperature of 100 degrees and the resultant temperature of their combined bulk will be 75 degrees. Further, if the air surrounding the vessel is 60 degrees the water in it will cool until the temperatures of the air and water are equalized.

METHODS OF HEATING.

1. Q. What methods are employed or what types of heating apparatus are used for warming buildings?

A. Open fires, stoves, hot air furnaces, steam, hot water, vacuum and vapor heating apparatus.

2. Q. How do the various systems compare or rank in cost of installation?

A. They rank (in the matter of first cost) very nearly in the order named. Of the more modern methods hot air is the cheapest. A steam heating apparatus costs about double that of a good furnace installation. The ordinary hot water apparatus about one-third more than steam, and vacuum and vapor heating costs from one-quarter to one-half more than steam, depending upon the type of system installed.

3. Q. How does each system rank in comparative running expense or cost for fuel?

A. Approximately a building requiring twelve tons of coal to warm it with hot air (with cold air supply) can be warmed by direct steam with nine tons of coal, by hot water with eight tons, and by a vacuum or vapor apparatus with eight or slightly less than eight tons of coal.

4. Q. What is the average life of each system and the cost for repairs during this period?

A. The average life of a furnace is from ten to twelve years with approximately twenty-five per cent. of its first cost expended for repairs. The average life of a steam boiler and system is from twenty to twenty-five years with perhaps ten to twelve per cent. of the original cost expended for repairs. The average life of a hot water job is twenty-five or thirty years with a possible expenditure of ten per cent. of its first cost for repairs.

As to the life of a vacuum or vapor job there is little available data, but there seems to be no reason why such an installation should not have a length of life equal to that of a steam or hot water apparatus.

5. Q. What is considered to be the best system of heati

A. The best system to install depends upon so many that it is hardly possible to give an intelligent answer tion.

Many houses and small buildings can be heated very satisfactorily with a furnace, and with the addition of a mechanically driven fan hot air heating is very satisfactory for buildings of larger size.

A steam heating apparatus is quick in action and in the results obtained, and there is no building but what can be heated successfully with steam if the apparatus is properly installed. It is particularly adapted for use in variable climates.

Hot water gives a very mild and even heat with little attention. and is particularly adapted for residence heating or for use in steadily cold or uniform climates.

Vapor and vacuum are considered quick and efficient for use in any climate.

It may be well to add that special methods of installation and special appliances increase the utility of any of the systems named.

CHIMNEYS AND FUELS.

1. Q. **Having selected the type of heating apparatus to be installed, what is the next important step to be taken in order that the apparatus shall prove successful and economical in operation?**

A. The provision of a good chimney of proper size.

2. Q. **What are the essential features of a good chimney flue?**

A. A round, or as nearly a square flue as circumstances will

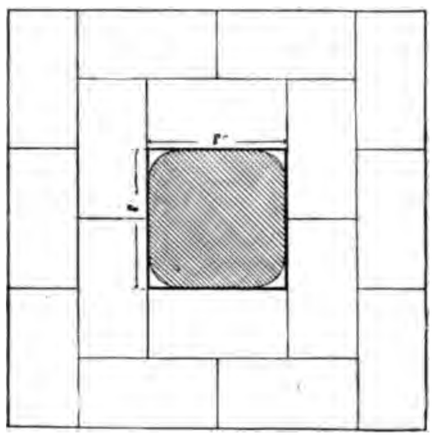


Fig. 1.—Plan of a Square Flue.

permit (Fig. 1), tile lined or well pointed; built straight up without offsets to a point well above the highest point of the roof. (Fig. 2). The chimney should have no other smoke-pipe opening than the one used for the heating apparatus.

3. Q. **Why should a chimney be built round or square?**

A. The smoke ascends a chimney spirally (Fig. 3); therefore there is no circulation in the corners of a square flue nor in the ends of a long narrow flue (Fig. 4).

4. Q. **Why should a chimney flue be lined with tile or well pointed?**

A. Friction of the ascending column of smoke and gases due to

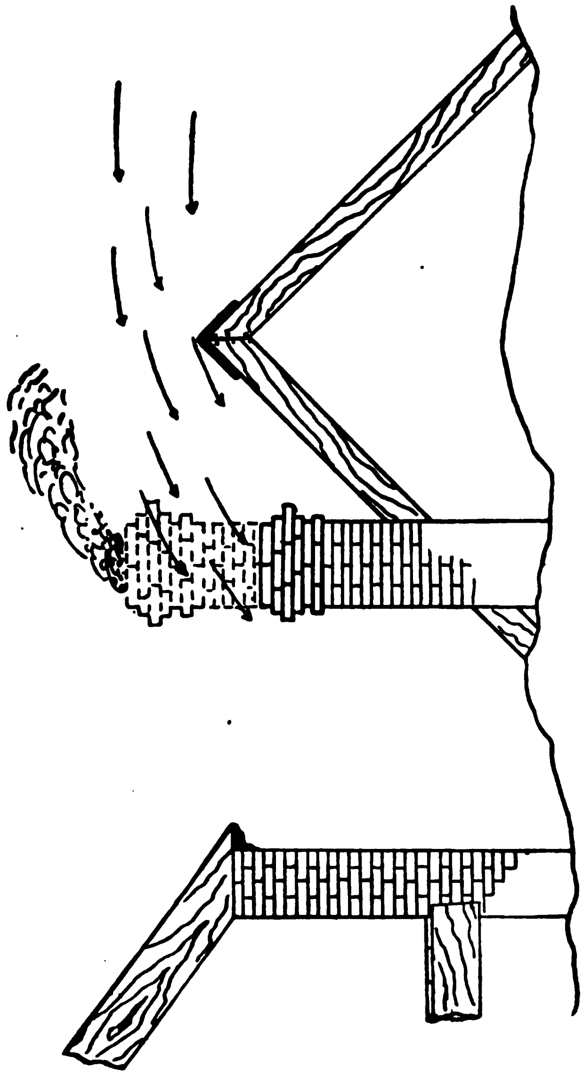


Fig. 2.—Illustrating Proper Height of Chimney.

particles of mortar overhanging in the flue is bad for the draft and reduces the capacity of the chimney, and for this reason the inside should be carefully smoothed or lined with tile. It is estimated that a 100 foot tile lined chimney will have fifty per cent. more capacity than an ordinary brick flue of the same height.

5. **Q. What two principal factors has a chimney flue?**

A. Area and height. Area for capacity and height for velocity. A chimney must be able to pass sufficient air to properly burn the fuel and carry off the smoke and products of combustion.

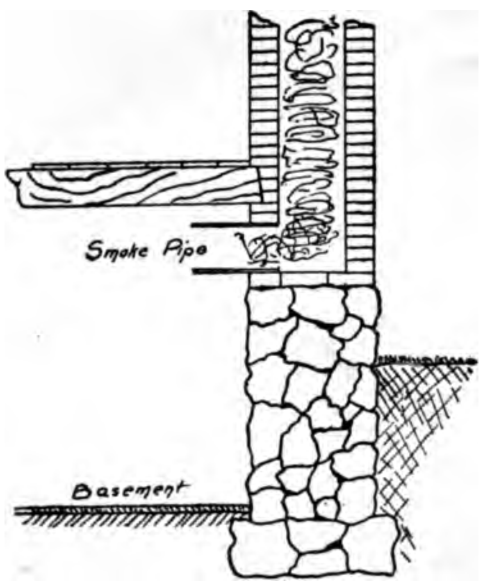


Fig. 3.—Smoke Ascends a Flue Spirally.

6. **Q. What is the easiest method of increasing the draft in a flue already built?**

A. Increasing its height increases the velocity and consequently adds to the effectiveness of the flue.

7. **Q. How is the required area of a chimney determined?**

A. By the area of the grate of the boiler or heater which it serves.

8. **Q. What shall be the area of a chimney flue as compared with the area of the grate of the heater?**

A. From one-eighth to one-tenth of the grate area. For the ordinary heating apparatus the chimney should not be smaller than 8 x 12 inches.

SIZES OF CHIMNEY FLUES.

Cubic Feet. Contents of Building.	Square Feet Direct Steam Radiation.	Square Feet Hot Water Radiation.	Round Tile or Iron Inside. Inches.	Square or Rectangular—Tile or Brick. Inches.
10,000– 20,000	250 to 450	300 to 800	8	8 x 8
20,000– 45,000	450 to 700	800 to 1200	10	8 x 12
45,000– 75,000	700 to 1,200	1,200 to 2,200	12	12 x 12
75,000–140,000	1,200 to 2,400	2,200 to 3,600	14	12 x 16
140,000–200,000	2,400 to 3,500	3,600 to 5,200	16	16 x 16
200,000–350,000	3,500 to 5,000	5,200 to 8,000	18	16 x 20

No chimney flue should be less than 8 x 8 inches square or 8 inches round, and a flue 8 x 12 inches will give better service.

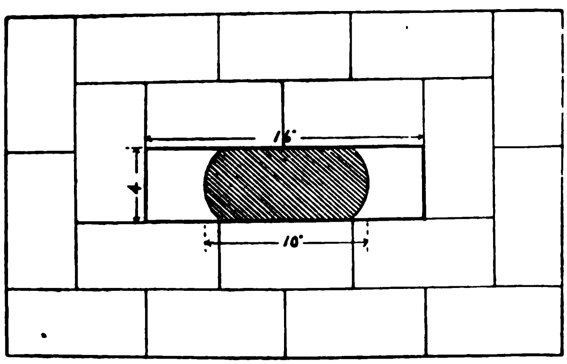


Fig. 4.—Effective Area of Long, Narrow Flue.

9. Q. What are some of the most frequent causes of trouble or failure on the part of the flue to operate properly?

A. Insufficient area or height, smoke pipe pushed into the chimney too far, the chimney being contracted or enlarged at some point, (Fig. 5), two or more smoke pipes entering the same flue, poor shape or construction, and too abrupt offsets or clogging with soot. (Fig. 6).

10. Q. What is combustion?

A. Combustion is a chemical action which produces heat.

11. Q. In burning coal, coke, gas, or other fuel what is necessary to produce combustion?

A. The mixing of oxygen with the fuel. The gas (carbureted hydrogen) and the carbon of the fuel must each be supplied with the necessary amount of oxygen and be kept at the required temperature to produce the chemical action necessary for perfect combustion.

12. Q. **How is the combustion of fuel in a heating apparatus calculated?**

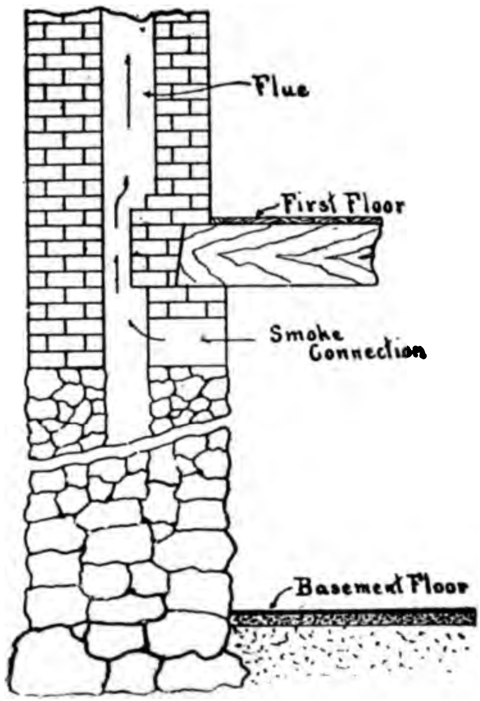


Fig. 5.—Effective Area of Contracted Flue.

A. By the pounds of fuel consumed per square foot of grate per hour.

13. Q. **What is the average rate of combustion in a low pressure steam boiler or house heating apparatus of modern type?**

A. It varies from three to five or six pounds of coal per square foot of grate per hour depending upon the size and character of the apparatus and the condition of the chimney flue.

14. Q. **What size of coal is the easiest to burn, and why?**

A. Large size, for the reason that it does not pack tightly and the large air spaces between the lumps of coal allow the air to pass through it freely and mix readily with the gases in the combustion chamber of the heater.

15. Q. **Why is the use of a smaller size of coal deemed advisable?**

A. It packs closer on the grate and acts as a check on the air passing through it. The air passing in smaller quantities is more

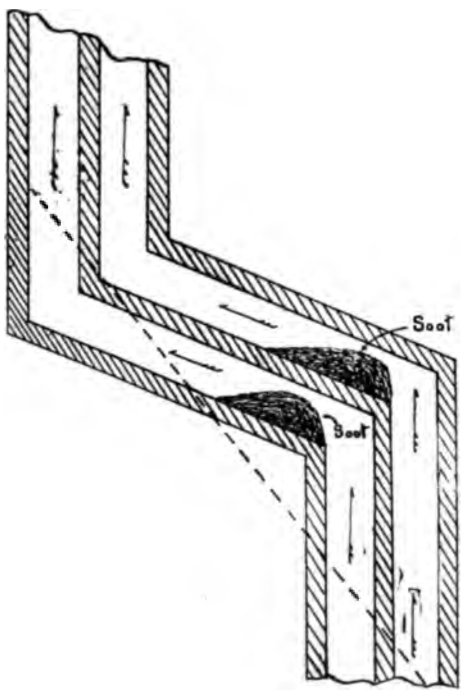


Fig. 6.—Effect of Soot in Offset of Flue.

readily heated and in mixing with the gases produces more perfect combustion.

16. Q. **What kind of coal is generally used for a heating apparatus, and why?**

A. Hard or anthracite coal because it burns at a slower rate of combustion; therefore lasts longer and is also cleaner to handle and use.

17. Q. **Why is hard coal cleaner and better than soft coal?**

A. Hard coal contains only a very small percentage of volatile

matter (gas)—usually seven or eight per cent.—and from eighty-five to ninety per cent. of carbon, while the better grades of soft coal contain from twenty to thirty-five per cent. of gaseous matter and impurities to from sixty to seventy-five per cent. of carbon. With the slow combustion required in ordinary heating apparatus the small amount of oxygen admitted is not sufficient to burn the gases in the soft coal without considerable smoking.

COMPOSITION OF COAL.

Kinds.	Volatile Matter (Gas).	Fixed Carbon.
Anthracite	7 per cent.	85 to 90 per cent.
Semi-Bituminous	18 " "	75 to 80 " "
Bituminous	24 " "	70 to 72 " "
Semi-Gas	30 " "	60 to 65 " "
Coking	33 " "	58 to 60 " "
Gas	37 " "	55 to 58 " "

Combustible Matter	Volatile Matter (Gas) Fixed Carbon (Coke)
Non-Combustible Matter	Moisture (Water) Ash (Refuse)
Impurities	Volatile Sulphur (Disappearing in Smoke) Iron Pyrites (Causing Clinkers)

18. Q. What attention should be given the boiler to provide for perfect combustion of the fuel?

A. Keep a good clean fire. Do not pack the coal tightly and keep the fire clear of ashes and clinkers. Slow and regular combustion is a preventative of clinkers.

19. Q. How should the fire be checked or combustion be retarded?

A. By closing tightly the draft door admitting air under the grate and checking the draft in the chimney by closing the damper, and if further checking is necessary by opening the check damper in the smoke-hood at the top of the boiler. Do not at any time open the firing door as by so doing the cold air will pass over the heating surfaces and chill the water in the boiler.

20. Q. How frequently should fuel be added for proper or economical firing?

A. Once every eight hours for severe weather, once every twelve hours for moderate cold weather, and once every twenty-four hours for mild weather.

21. Q. What should be the amount of fuel required for a low pressure steam or hot water boiler?

A. A very fair estimate is one ton of anthracite coal per radiator per heating year (six months) allowing 50 square feet of radiation for a steam radiator or 75 square feet for a hot water radiator.

22. Q. What exceptions should be made to this rule?

A. The addition of improved modern specialties to a heating plant such as accelerating devices for hot water and vapor and vacuum devices for steam will increase the efficiency of a heating apparatus, and reduce the amount of fuel required. Poor methods of firing, carelessness of attention, and certain conditions of draft and chimney construction will increase the amount of fuel required.

BOILERS FOR HEATING.

1. Q. **What types of boilers are commonly used for heating?**

A. Cast iron sectional boilers, either round or square, having vertical or horizontal sections, and round steel or wrought iron boilers for small installations, and fire-box, tubular or water-tube boilers for large installations.

2. Q. **Which type of boiler is most generally used?**

A. The cast iron boiler either round or square.

3. Q. **Why is cast iron preferred to wrought iron or steel in boiler construction?**

A. Cast iron is considered to be less susceptible to rust than wrought iron or steel and therefore is thought to be the better material for a heating boiler that is idle or out of service a good portion of the year.

4. Q. **Why will wrought iron or steel rust more quickly than cast iron?**

A. Cast iron is simply melted ore with most of the impurities removed which is moulded into the various castings of which the boiler is composed. It is porous and not likely to rust. The finer iron is worked the more the pores are removed and the greater will be its tendency to rust.

5. Q. **What two factors are necessary in boiler construction?**

A. Heating surface and grate surface.

6. Q. **What is meant by heating surface?**

A. The heating surface of a boiler is of two kinds, direct surface and flue surface. Direct surface is that portion of the boiler above and surrounding the fire against which the direct heat from the fire strikes or against which the direct heat waves from the fuel impinge. Indirect or flue surface is that which receives the heat from the burning gases in their exit from the combustion chamber into the smoke flue.

7. Q. **What is meant by grate surface?**

A. The grate surface of a boiler is the cradle or surface that holds or supports the fuel and is proportioned according to the amount of heating surface contained in the boiler and to the radiating surface (square feet of radiation) necessary for a building.

8. Q. **How can the amount of grate surface required in a boiler be determined on a heat unit basis?**

A. Determine the loss in heat units per hour for the entire

building. Dividing this sum by an amount equalling 60 per cent. of the heat value of the coal to be used for fuel (if a good quality of anthracite containing 14,500 B. T. U. per pound — 14,500 × .60 = 8,700) gives the weight of fuel to be burned per hour. Divide this result by 3 or 4 for small boilers or 5, 6 or 7 for larger boilers (these divisors representing the rate of combustion per hour) and the result will be the grate surface required.

9. **Q. How are fire-box, tubular, and water-tube boilers rated?**

A. By their horse-power.

10. **Q. What is meant by the term "horse-power"?**

A. A horse-power (H. P.) is the amount of work required to raise 33,000 pounds one foot high per minute, which is equivalent to 42.5 heat units per minute and which represents the energy developed by evaporating 2,665 pounds of water into steam.

11. **Q. How is the horse-power of a tubular boiler calculated?**

A. Each 15 square feet of heating surface is considered equivalent to one horse-power.

12. **Q. How are cast iron boilers rated?**

A. Their rating should be based on the amount of coal consumed per square foot of grate surface and their efficiency. The character of construction to a large degree determines the efficiency. Boilers which have a large prime or direct heating surface in proportion to the size of grate are more efficient than boilers with a large amount of indirect surface.

13. **Q. Why is a boiler with a large proportion of direct heating surface most efficient?**

A. Direct surface is more efficient than indirect or flue surface, the proportion being about three to one. There should be only sufficient flue surface to assist in consuming the gases and extract the heat from the products of combustion before they leave the boiler.

14. **Q. How is the radiating capacity of a heating boiler usually rated and listed by manufacturers?**

A. By the square feet of direct radiation (gross), steam or hot water which a boiler of any certain size will supply for an eight hour period of firing.

15. **Q. What is meant by "gross" amount of direct radiation?**

A. Boiler power or capacity is calculated at the boiler outlet, therefore provision must be made for all piping as well as radiators. (Various kinds of radiating surfaces, direct, semi-direct and indirect, are discussed elsewhere in this book.)

BOILER TRIMMINGS AND SETTING.

1. Q. What trimmings are used on a steam boiler used for heating?

A. A safety valve of the weighted or pop (spring) variety, a low pressure steam gauge, a water column with water glass and try-cocks, a damper regulator and a draw-off cock.

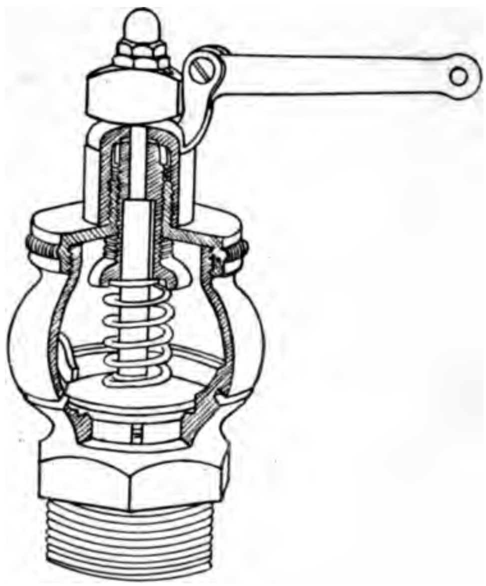


Fig. 7.—Pop Safety Valve.

2. Q. Where should the safety valve be located and for what purpose is it used?

A. The safety valve (Fig. 7) should be located at the top of the boiler and it is used to relieve excessive pressure of steam when the pressure has accumulated to a point considered dangerous.

3. Q. What is the maximum pressure commonly allowed on low pressure boilers?

A. From eight to fifteen pounds, depending upon the size and character of the boiler.

4. **Q. At what point on the boiler is the steam gauge located and what is its purpose?**

A. The steam gauge (Fig. 8) should be located above the boiler and should be connected to it, or to the pipe connection to the water column, by a siphon. Its purpose is to register the pressure in pounds per square inch of the steam within the boiler.

5. **Q. What is the water column (and gauge), where is it located, and for what purpose is it used?**

A. The water column (Fig. 9) is a hollow cylindrical casting having a water glass extending nearly its entire length. It is also tapped for and provided with two or three try-cocks. It is located at the side of the boiler at such a height that the glass

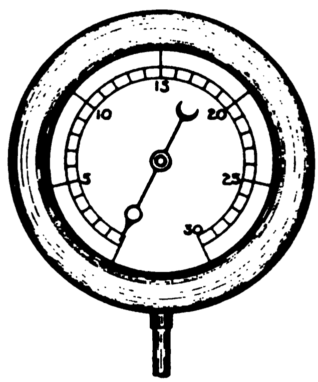


Fig. 8.—Steam Gauge.

will be about half full when the boiler is filled with water to the normal water-line. The top of the water column is connected to the steam chamber of the boiler and the bottom of it to the water space of the boiler, and its purpose is to show in the glass the height of the water in the boiler.

6. **Q. Why is the water column connected to the boiler as above described?**

A. In order that the steam pressure will be the same on the water in the glass as it is upon the water in the boiler so that the water-line will show its true height in the glass when steam is carried at various pressures on the boiler.

7. **Q. What is meant by a damper regulator?**

A. A damper regulator (Fig. 10) is a device connected to the

steam space of the boiler which regulates the draft and check doors of the boiler, and is operated by the pressure of steam carried.

8. Q. How is a common form of damper regulator made and how does it operate?

A. Two castings in shape similar to an old-fashioned soup plate are bolted together at the rim with a rubber diaphragm

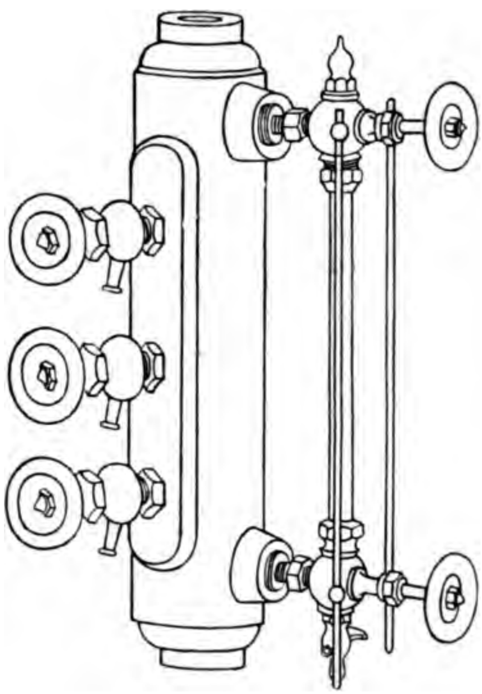


Fig. 9.—Water Column and Gauge.

between them. A plunger, resting on the rubber, protrudes through an opening in the center of one of the castings. This device is connected to the steam chamber of the boiler by a nipple or short piece of pipe in such a manner that the pressure of steam against the under side of the rubber will force it against and raise the plunger (which is on the upper side of the device). Connected to a lip of the casting and resting across the plunger is a long iron rod from the ends of which chains connect with the damper doors. As steam raises the plunger the rod tilts and operates the damper

doors of the boiler, the extent of this operation being governed by movable weights placed on the rod; these weights are adjusted according to the requirements of the work.

9. Q. How should the chains be connected from damper rod to draft doors?

A. In such a manner that when both draft and check doors are closed the damper rod will be level horizontally.

Note by Fig. 11 that weight C on the rod B is set away from the regulator and holds open the draft door E. A very little pressure of steam against the diaphragm of the regulator will raise the rod to a level position, closing the draft door E as shown by the second position. Should this not check the fire sufficiently and the pressure continue to accumulate against the diaphragm it will

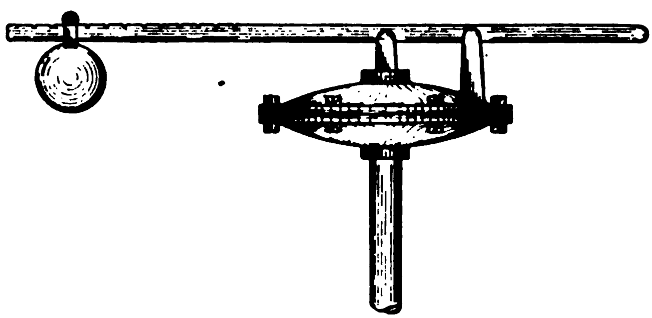


Fig. 10.—Old Style Damper Regulator.

raise the rod until it opens the check door F as shown by the third position. The diaphragm regulator is shown at A, the smoke hood at D and G represents the smoke pipe.

10. Q. What is a draw-off cock?

A. A water cock or valve having a full size free opening through it which is placed at an extreme low point of the boiler for the purpose of draining the water and sediment from it. If properly constructed the cock should have a pipe thread at one end for screwing into an opening of the boiler and a hose thread at the opposite end for attaching a hose.

11. Q. What trimmings are necessary for a fire-box or tubular boiler used for heating?

A. If used for low pressure heating the trimmings are substantially the same as are required for a cast iron boiler.

12. Q. What setting is used for cast iron boilers?

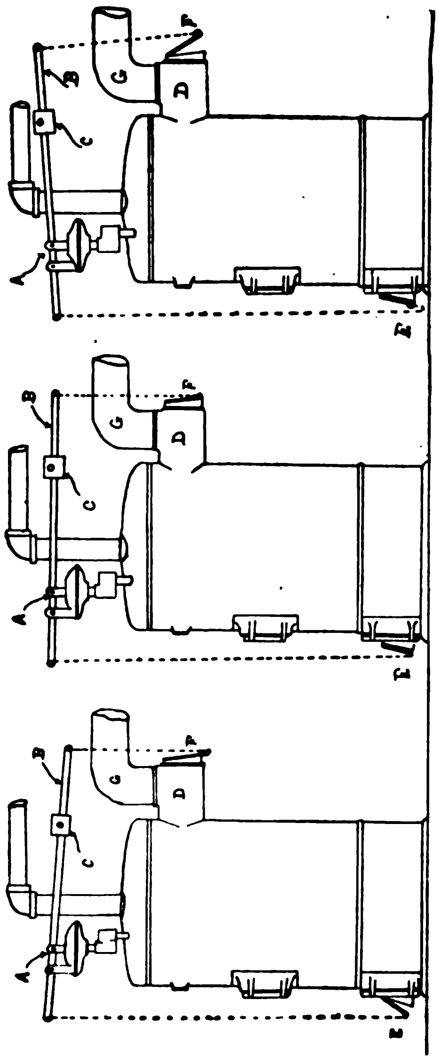


Fig. 11.—Method of Attaching Damper Chains.

A. The old method of setting cast iron boilers, particularly those of large size, was to enclose them by walls of common brick and by lining with fire brick any part of the setting which came in contact with the fire. At this date nearly all cast iron boilers have a portable setting. The sections are bolted together and the exterior surface (excepting doors and front plate castings) are covered with plastic magnesia or asbestos cement.

MATERIAL FOR BRICK WORK OF TUBULAR BOILERS.

Boilers — Single Setting.	Common Brick.	Fire Brick	Sand Bushels.	Cement Barrels.	Fire Clay Pounds.	Lime Barrels.
30″ x 8′	5,200	320	42	5	192	2
30″ x 10′	5,800	320	46	5½	192	2¼
36″ x 8′	6,200	480	50	6	288	2½
36″ x 9′	6,600	480	53	6½	288	2¾
36″ x 10′	7,000	480	56	7	288	3
36″ x 12′	7,800	480	62	8	288	3¼
42″ x 10′	10,000	720	80	10	432	4
42″ x 12′	10,800	720	86	11	432	4¼
42″ x 14′	11,600	720	92	11¾	432	4½
42″ x 16′	12,400	720	99	12½	432	5
48″ x 10′	12,500	980	100	12½	590	5¼
48″ x 12′	13,200	980	108	13½	590	5½
48″ x 14′	14,200	980	116	14½	590	5¾
48″ x 16′	15,200	980	124	15½	590	6
54″ x 12′	13,800	1,150	108	13¾	690	5½
54″ x 14′	14,900	1,150	117	15	690	6
54″ x 16′	16,000	1,150	126	16	690	6¼
60″ x 10′	13,500	1,280	108	13½	768	5½
60″ x 12′	14,800	1,280	118	14¾	768	6
60″ x 14′	16,100	1,280	128	16	768	6½
60″ x 16′	17,400	1,280	140	17½	768	7
60″ x 18′	18,700	1,280	148	18¾	768	7½
66″ x 16′	19,700	1,400	157	19¾	840	8
66″ x 18′	21,000	1,400	168	21	840	8½
72″ x 16′	20,800	1,550	166	20¾	930	8½
72″ x 18′	22,000	1,550	175	22	930	9

13. **Q. What setting is used for tubular or fire-box boilers?**

A. Tubular or fire-box boilers are set in brick work. The outer and end walls should be constructed of best hard burned brick laid in cement and lime mortar. The fire-box lining should be made of best fire brick laid on flat in thin clay mortar with close joints and occasional header courses. The bridge wall should be faced (at least partially) with fire brick. The ash pits and a small space in front of the boiler should be paved with common brick laid on edge.

RADIATION.

1. **Q. What is meant by the term "Radiation" or "Radiating Surfaces"?**

A. As applied to heating, radiation means some form of hollow metal surface through which steam or hot water is circulated and which, by contact with the air surrounding it (this air being very much cooler), cools the steam or water, imparting its heat units to the air of the room to be warmed.

2. **Q. Of what material is the usual type of radiator constructed?**

A. Cast iron or wrought iron. The early type of radiators

Fig. 12.—A Box Coil.

were made of wrought iron tubes screwed into a cast iron base. The manufacture of this type of radiator has been almost, if not entirely, discontinued. A stack of piping termed a "box coil" was also largely used in the early days of steam heating. Fig. 12. This was sometimes encased with ornamental cast iron panels or scroll work and covered with an iron or marble top. Radiating surfaces made of wrought iron as at present employed are usually designated as pipe coils. The radiators commonly used are cast iron made up of sections nippled together. Radiators with loops made of sheet steel are also used to some extent.

3. **Q. For what class of heating are pipe coils generally employed?**

A. As radiating surface for warming factory buildings, greenhouses or conservatories, garages and other buildings where the appearance of a pipe coil is not objectionable.

4. **Q. What styles of pipe coils are in general use?**

A. Corner coils, "harp" or mitre coils, and return-bend or "trombone" coils.

5. **Q. What is a corner coil?**

A. A corner coil, as its name implies, is one which is located at and turns a corner of a room, the elbows used on the piping

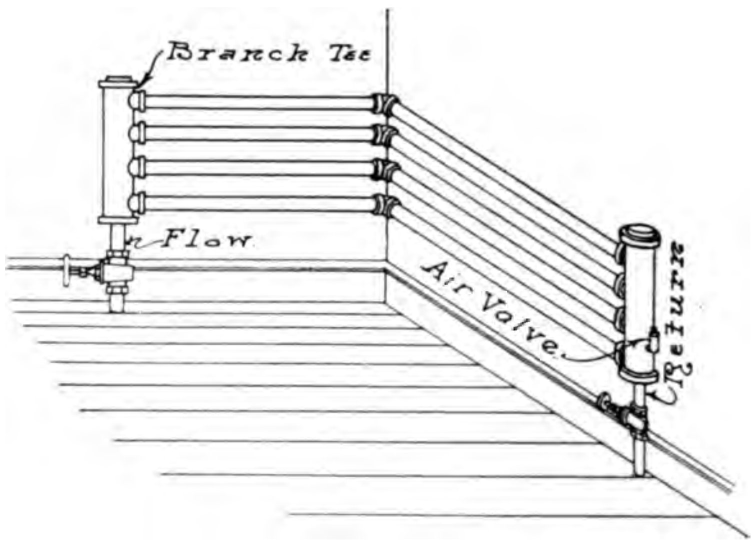


Fig. 13.—A Corner Coil.

at the corner providing for the expansion and contraction of the pipes. Manifolds or branch-tees are usually employed in building this style of coil. Fig. 13.

6. **Q. What is a "harp" or mitre coil?**

A. A coil built with a mitre and shaped like the letter L, the short end of the mitre being placed vertically when the coil is hung in position. The mitre is used in order that the elbows will provide for expansion and contraction. Fig. 14.

7. **Q. What is a return-bend coil?**

A. A return bend coil is a coil constructed with return bends

to allow for the expansion and contraction and its construction allows a continuous flow of the steam or hot water through a single pipe. Fig. 15.

8. Q. In building or making up a manifold coil what fittings are used?

A. The neatest method is to employ right and left elbows at the mitre. Common elbows may be used and the pipes joined to the manifold with long screws or lock or jam nuts.

9. Q. Which type of radiator is the best for general use—cast or wrought iron?

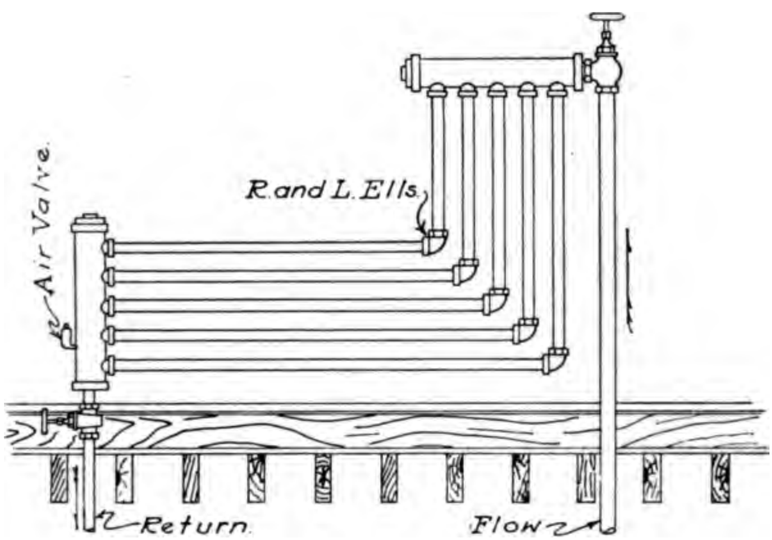


Fig. 14.—A "Harp" or Mitre Coil.

A. There is not much difference. Wrought iron radiators are, if anything, more efficient, but are hardly as desirable as cast iron radiators owing to the fact that cast iron radiators are made up of loops or sections of several heights and widths, and a variety of shapes and sizes may be had to fit any desired space.

10. Q. How many types or kinds of radiating surface are in use?

A. Three; the several types of radiators are known as direct, semi-direct or direct-indirect and direct radiation.

11. Q. What is a direct radiator?

A. Direct radiators are so called because they are located in

the room to be warmed and give off their heat directly to the air within the room.

12. **Q. Describe a direct-indirect or semi-direct radiator.**

A. Direct-indirect or semi-direct radiators are so arranged that they will warm fresh air conveyed from outside the building through a duct or opening through the wall to a boxing forming the base of the radiator, the air being warmed by passing upward over the surface of the radiator as it enters the room. The duct and base are provided with dampers so that the fresh air inlet may be closed and when closed the radiator can be used as a direct radiator. Fig. 16.

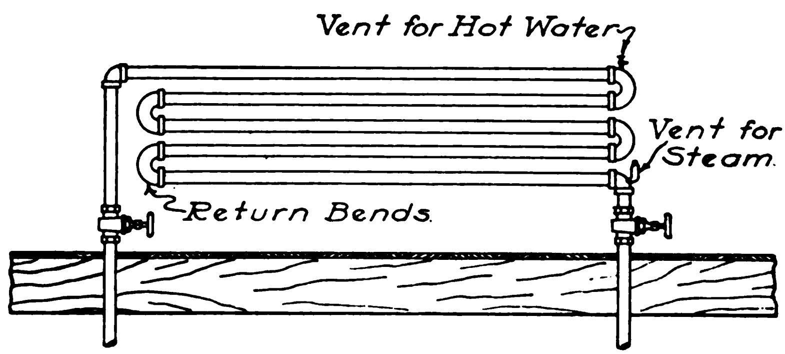


Fig. 15.—A Return Bend or "Trombone" Coil.

13. **Q. Describe an indirect radiator and the indirect method of heating.**

A. Indirect radiators are located outside of the room to be heated and warm the room indirectly by warming a supply of air which is then introduced into the room through a duct and register. They are commonly located below the room to be heated although they may be located adjacent to it. The radiator is encased in a boxing and a cold air supply from outside the building connects with the boxing. Fig. 17.

14. **Q. At what point in a room should a direct radiator be located?**

A. Along the most exposed and coldest wall of the room or under a window on this side of the room.

15. **Q. Why should the radiator be placed on the cold side rather than on an inner wall of the room?**

A. When located in this position the radiator will condense

more steam or cool the hot water more and therefore give off more heat to the surrounding air than when located along an inner wall or in a warmer position. The radiator along an exposed wall draws the cold air to it, warms and expands the air, causing

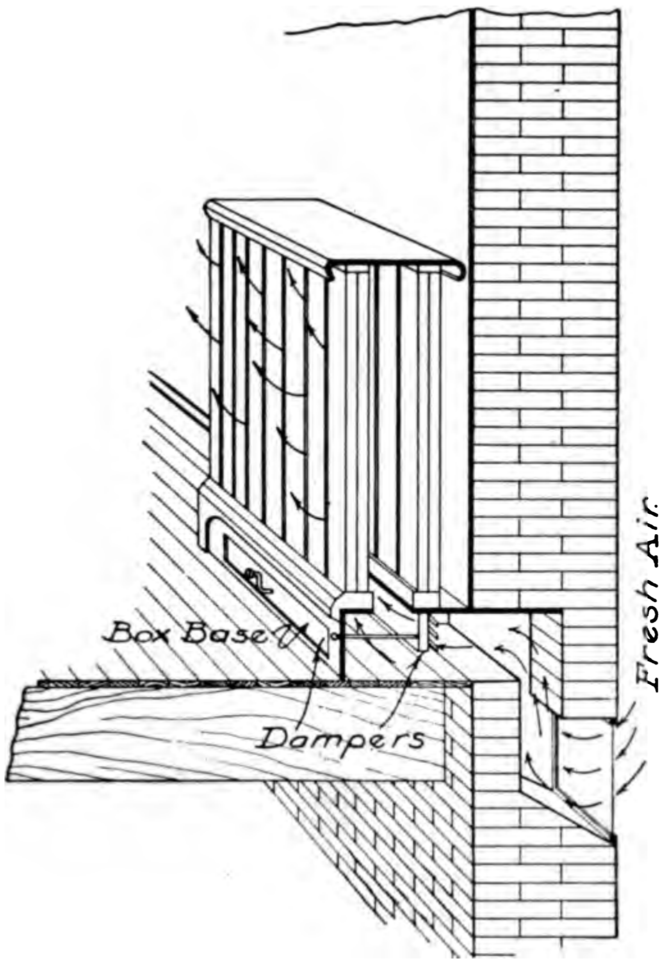


Fig. 16.—A Direct-Indirect Radiator.

it to rise, and thus creating a circulation or turning of the air within the room. If placed on an inner wall the radiator will draw the colder air across the floor of the room and thus cause uncomfortable and dangerous drafts.

16. Q. What should be the location of a direct-indirect radiator?

A. The same as a direct radiator. For the same reasons and further that it is necessary to provide for an inlet through the outer wall for the fresh air supply to the radiator.

17. Q. At what point should an indirect radiator be located?

A. The radiator itself should be located near to the register, and the location of the register in a room should be in the inside wall or in the floor near the inside wall, or exactly the reverse of the location for a direct radiator.

Fig. 17.—An Indirect Radiator.

18. Q. What is meant by the word "stack" as applied to indirect radiation?

A. Several sections of an indirect radiator when bolted and nippled together, or assembled, are frequently referred to as a "stack" or an "indirect stack."

19. Q. How is a stack of indirect radiation placed in position for service?

A. It should be hung or suspended from the ceiling of the basement on suitable hangers and covered with a casing made of galvanized iron or beaded boards lined with tin. The stack should be hung in such a position that when encased there will be an air space of from eight to ten inches in height above the radiator, and from six to eight inches below it, and the casing should fit

tightly around the sides in order that the air will pass between the sections and not around them. The cold air should enter at the bottom of one end of the casing, and the hot air should be taken from the top of the opposite end. Fig. 19.

20. Q. **What air supply is necessary for an indirect radiator?**

A. As a rule it is well to be generous in the size of air ducts,

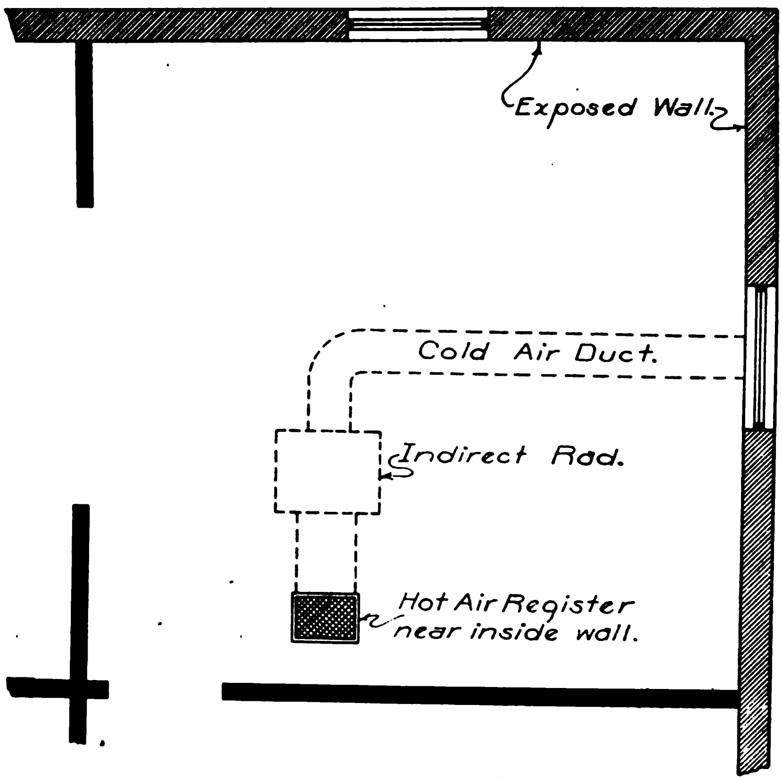


Fig. 18.—Proper Location of Indirect Radiator.

both cold and hot, for use with indirect radiation, as each duct should be provided with a damper which may be utilized to reduce the air supply. It is a hard matter to increase the efficiency of too small an air duct.

From 1 to 1½ square inches of area to each square foot of radiation for the hot air duct, according to the size of the radiator, is a good rule to employ, and the area of the cold air duct sho

2/3 to 3/4 of the area of the hot air flue. When the radiator serves an upper floor the area of the hot air duct may be decreased from 20 to 25 per cent. and the area of the cold air duct may be slightly increased.

SIZES OF AIR DUCTS AND REGISTERS FOR INDIRECT HEATING.

Sq. Ft. of Rad'n.	Cold Air Duct to Stack.		Warm Air Duct		Registers.		Radiator Tappings. Inches.
	For First Floors Square Inches.	For Upper Floors Square Inches.	For First Floors Square Inches.	For Upper Floors Square Inches.	For First Floor Inches.	For Upper Floors Inches.	
40	40	35	60	40	10 x 12	8 x 10	1 x 3/4
50	50	40	75	50	10 x 12	8 x 10	1 x 3/4
60	60	45	90	60	10 x 14	8 x 12	1 1/4 x 1
70	70	50	105	70	12 x 15	10 x 12	1 1/4 x 1
80	80	60	120	80	12 x 15	10 x 12	1 1/4 x 1
90	90	70	135	90	12 x 19	10 x 14	1 1/2 x 1 1/4
100	100	75	150	100	12 x 19	12 x 15	1 1/2 x 1 1/4
120	110	90	170	110	16 x 16	12 x 15	1 1/2 x 1 1/4
140	120	105	190	120	16 x 18	12 x 18	2 x 1 1/2
160	130	120	210	130	16 x 20	12 x 20	2 x 1 1/2

21. **Q. What should be the size of the registers for indirect heating?**

A. The effective register area should be about 25 per cent. greater than the area of the hot air flue connecting with it.

22. **Q. What factors determine the amount of radiating surface necessary for a building?**

A. The cooling surfaces of the building.

23. **Q. What are the cooling surfaces of a building?**

A. The cubic feet of air in the same (cubical contents), the outside or exposed wall surfaces, and the glass surface (windows and outside doors), outside doors being considered as glass surface.

24. **Q. How is the right amount of radiation determined for each room in the building?**

A. There are a number of good rules for this purpose, any one of which is reasonably accurate when used with judgment and when the various phases of building construction, location and exposure are considered.

One of the more simple rules is called the Mills rule or the rule 2-20-200; that is, for steam heating allow one square foot of radiation for each 2 square feet of glass, one for each 20 square feet of exposed wall surface, and one for each 200 cubic feet of contents.

For hot water heating add 60 per cent. to the amount required for steam.

Figure separately for each room and tabulate the result to show the total radiation required.

For example, consider a room 12′×16′ in size having a ceiling 10′ high, the 16′ side of the room an outside wall and two windows

Fig. 19.—Method of Boxing an Indirect Radiator.

3′ × 6′.

12 × 16 × 10 = 1920 cubic feet of contents.
16 × 10 = 160 square feet of exposed wall.
3 × 6 × 2 = 36 square feet of glass.
1920 ÷ 200 = 10 feet for cubical contents.
160 ÷ 20 = 8 feet for exposed wall.
36 ÷ 2 = 18 feet for glass.

Total 36 feet for steam.

36 + 21 (60 per cent.) = 57 feet for hot water.

25. Q. What condition other than size and amount of wall and glass governs the estimating of all radiation?

A. The location of the rooms to be warmed; whether located on the north or exposed side of the building or on the south or warm side of the same.

26. Q. How are these conditions covered when estimating?

A. For rooms on the north or exposed side of the building add 10 per cent. to the amount obtained by the rule, and for rooms on the south or warm side of the building deduct 10 per cent. When locating the radiation in a large room such as a church or public auditorium exposed on all sides, approximately 10 per cent. more radiation should be placed on the north side than on the south side.

27. Q. What rooms in a residence require special consideration when estimating radiation?

A. The halls, dining room and bath room.

28. Q. What special treatment is necessary for each of these rooms?

A. When estimating radiation for the hall, both lower and upper halls should be considered together and the total radiation required should be placed in the lower hall unless the upper hall is very much exposed and isolated from the lower hall. The dining room should be warmed particularly well, as being the first of the living rooms to be occupied in the morning it should be quickly warmed, thus requiring plenty of radiation.

The bath room should have from 25 to 30 per cent. more radiation than the amount obtained by rule, as all bath rooms should be particularly well warmed.

29. Q. How is the amount of radiation required for direct-indirect heating ascertained?

A. By adding 25 per cent. for steam, or 35 per cent. for hot water, to the amount of direct radiation obtained by rule.

30. Q. How is indirect radiation computed?

A. By adding 50 per cent. for steam, or 75 per cent. for hot water, to the amount of direct radiation required.

31. Q. What amount of radiation is required for vapor heating?

A. Approximately 15 per cent. more than is necessary for steam. A very good rule for computing radiation for a vapor system is to multiply the cubical contents by 1½, the exposed wall surface by 25 and the glass surface by 75, add the results together and divide the total by 200.

For example, consider a corner room 12′ × 15′ in size having a ceiling 10′ high, one outside door (with transom) 3′ × 8′ and one window 4′ × 6′.

12 × 15 × 10 = 1800 cubic feet of contents.
12 + 15 × 10 = 270 square feet of exposed wall.
3 × 8 + 4 × 6 = 48 square feet of glass.

1,800 × 1½ =	2,700
270 × 25 =	6,850
48 × 75 =	3,600
	13,150

13,150 ÷ 200 = 65 square feet radiation for vapor.

32. Q. **What conditions require the addition of the various percentages for hot water or vapor heating to the amount required for steam?**

A. Radiation required is based upon the maintenance of 70 degrees inside temperature with the thermometer at zero outside, and radiation for steam heating based upon a pressure of 2 pounds or a temperature of 219 degrees hot water upon a temperature of 180 degrees and vapor upon a temperature of 212 degrees (atmospheric pressure) or a few ounces above atmospheric pressure.

STEAM HEATING.

1. **Q. How many systems of steam heating are in general use?**

A. Strictly speaking there are but two—high pressure and low pressure; although there are several modifications or methods of installing each system.

2. **Q. Which system is most frequently used when installed for heating purposes only?**

A. The low pressure gravity return system.

3. **Q. What methods may be employed in installing this system?**

A. The one-pipe or the two-pipe method, employing a wet or dry return. The one-pipe method may be installed as a circuit system, or as a divided circuit system, or a relief system without returns. The two-pipe system may be installed according to the regular method by which both flow and return mains are run in basement, or by the overhead method with the mains run overhead and the returns only in the basement. The overhead method might properly be called a combination of the one-pipe and two-pipe systems.

4. **Q. Why are these methods designated as low pressure gravity return systems?**

A. Because of the fact that in the installation of each system the piping is so arranged that the water of condensation from the radiators returns to the boiler by gravity.

5. **Q. What is meant by low pressure steam?**

A. Steam at a pressure of from one to five pounds is ordinarily considered as being low pressure although this pressure is often increased to eight or ten pounds on a low pressure apparatus.

6. **Q. What is meant by high pressure steam as used for heating apparatus?**

A. The ordinary acceptance of the term is the heating of buildings from high pressure or tubular boilers which are themselves used for power or for purposes other than supplying steam to the heating apparatus. The pressure may be 30, 40, 50, 100 pounds, or more.

7. **Q. Is it customary to use steam at high pressure in a heating apparatus?**

A. No. The steam pressure is ordinarily reduced by placing a pressure reducing valve on the steam line, reducing it to a nominal pressure in the heating apparatus.

8. Q. What form of heating from high pressure boilers is used to a great extent?

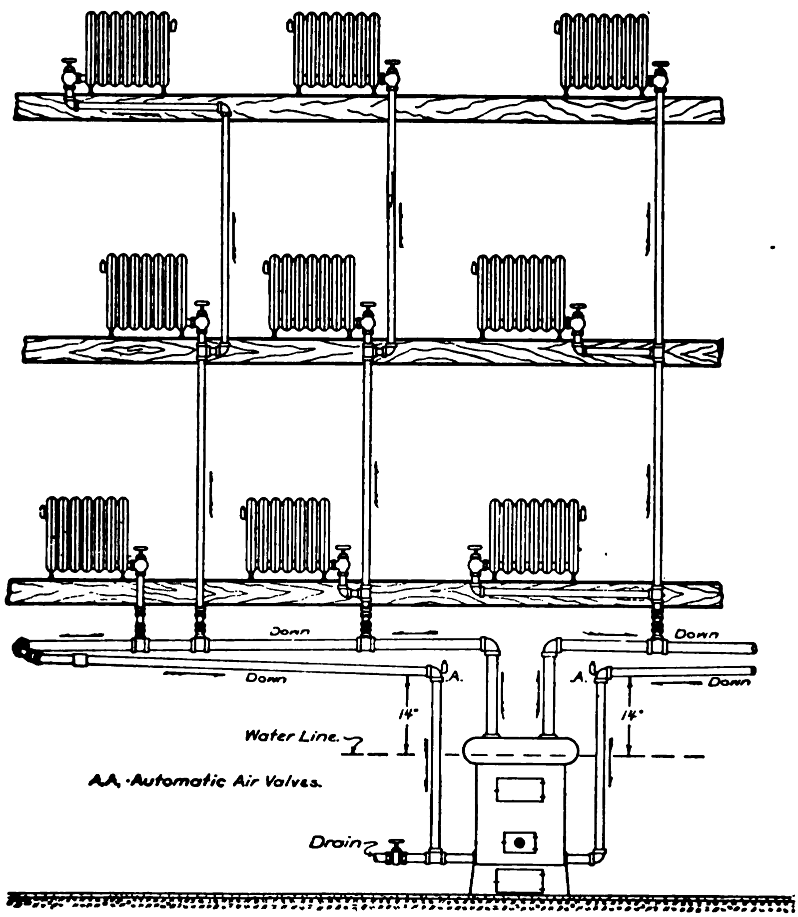


Fig. 20.—The One-Pipe Method of Steam Heating.

A. Exhaust heating.

9. Q. What is meant by exhaust heating?

A. Steam is supplied at high pressure to an engine, pump or other mechanical appliance requiring steam for power. The steam after accomplishing its work in the cylinders escapes through

an exhaust pipe and but a very small percentage of its heating value (possibly from 5 to 7 per cent.) has been utilized by the engine or pump, and instead of allowing this steam to escape to the atmosphere it is turned into the heating apparatus.

10. Q. **For what other purpose is the exhaust steam commonly used?**

A. To heat the boiler feed water. It is passed through an apparatus called a feed water heater which heats the water required for boiler feed purposes.

11. Q. **About how much of the value of the steam is required to heat the feed water for the boiler?**

A. Approximately 15 per cent. It is estimated that after passing through the cylinders of the engine or pump and the feed water heater there is still from 60 to 80 per cent. of its value left for heating purposes, the amount depending upon the character of the engine or pump employed.

12. Q. **What is the one-pipe method of circulating steam?**

A. The one-pipe method is that which has only a single pipe connection to each radiator, the branch or feed pipe being arranged to act as both flow and return, and a single main pipe conveys the steam to the radiator and returns the condensation to the boiler. Fig. 20.

13. Q. **How should the supply branch be connected to the radiator?**

A. Always at the bottom of one end of the radiator, employing but one valve in making the connection.

14. Q. **How is the main flow pipe run on a single pipe system?**

A. The main (or mains—there may be more than one) is usually taken from the top of the boiler to a point within a few inches of the ceiling above, from which point it pitches downward to the end of the line, the pitch being from one-half to one inch in each ten feet of length.

15. Q. **Can the main be installed so as to pitch upward from the boiler if circumstances so require it?**

A. Yes, provided it is dripped or relieved at the low point in order not to form a trap for the return water of condensation.

16. Q. **What is a relief system?**

A. A system on which all mains or flow pipes pitch upward from the boiler, each being provided with a drip or relief pipe at a point near the boiler through which all condensation is returned

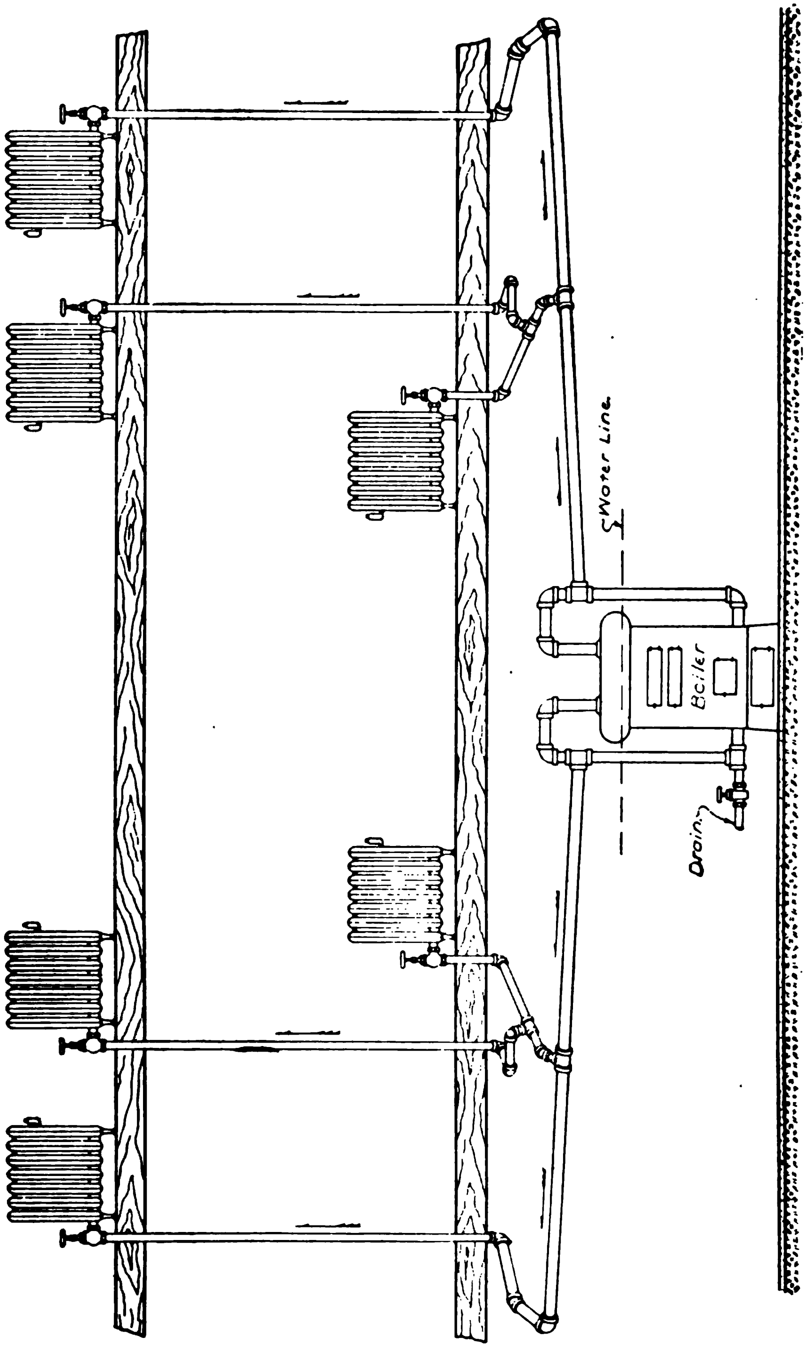


Fig. 21.—The Relief System of Steam Heating.

to the bottom of the same. The condensation from radiators and piping may also be dripped or relieved by drip connections at the base of each riser or radiator connection, these being connected to a wet return. Fig. 21.

17. **Q. What is the circuit system of piping and how is this system installed?**

A. A circuit system is one on which a single steam main rises from the boiler to as high a point as convenient and then makes a circuit of the basement supplying the various radiators by branches taken from the main pipe as occasion requires. As a rule this main terminates at a point near the boiler and an automatic air valve is placed on the end and a drop made with a smaller pipe into a return opening of the boiler. Fig. 22.

18. **Q. What should be the difference in height between the end of the main and the water line of the boiler?**

A. Not less than 14 inches and a height of 18 inches is preferable.

19. **Q. What conditions govern the height of the end of the main or the distance between it and the water line of the boiler?**

A. The size and length of the main as proportioned to the square feet of radiation or condensing surface on the job. The element of friction due to fittings and valves on the main is also considered, as friction reduces the velocity of the steam which affects the pressure drop at the end of the main. As the steam pressure on the water in the boiler is much greater than on the water in the return at the end of the line there is a point of equalization in the return and this may be anywhere from 6 to 20 inches or more above the water line, but on a carefully designed system should not exceed 12 or 14 inches; therefore a distance of 14 inches between the end of the main and the water line of the boiler should be sufficient.

20. **Q. What is the divided-circuit system?**

A. This system is similar in all respects to the circuit system except that the location of the boiler or shape of the building may make it advisable to run the main in two circuits, one in either direction.

21. **Q. How should the returns be connected on a divided-circuit system?**

A. The mains usually terminate at a point in the basement distant from the boiler and an automatic air valve should be placed on the end of each main and the returns or bleeders from the ends

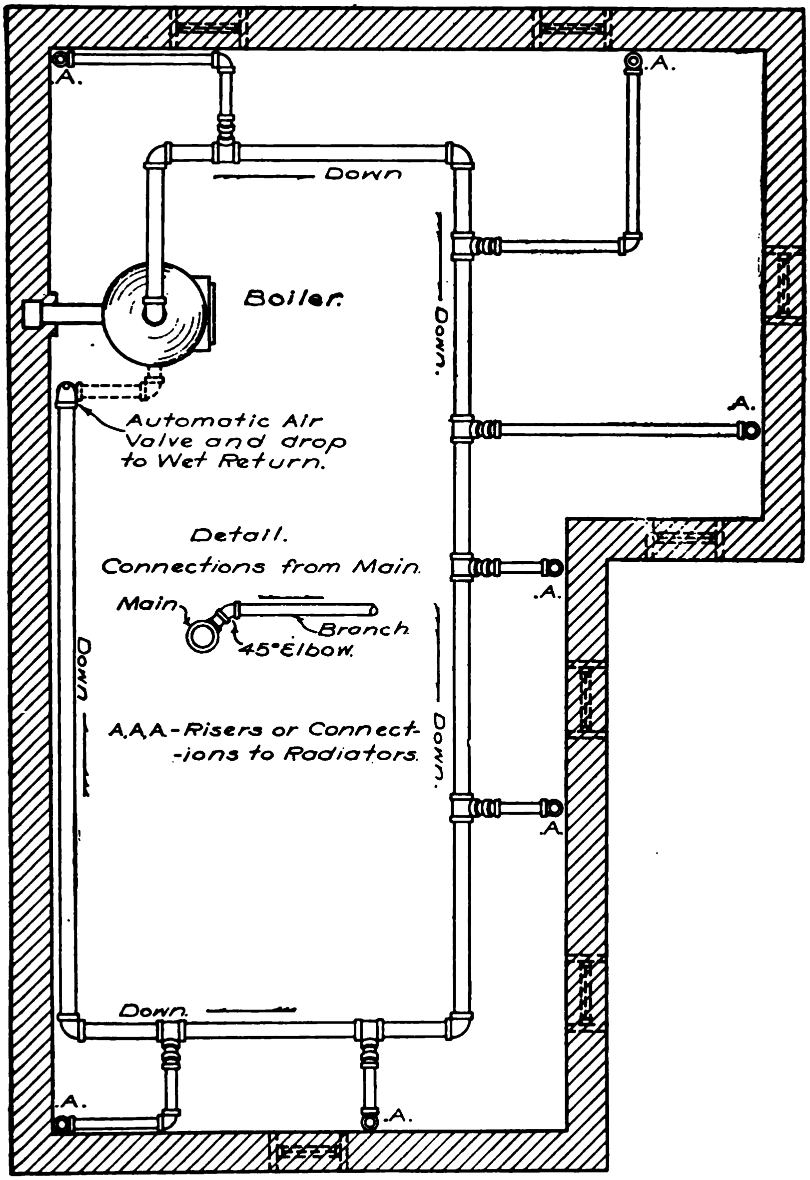


Fig. 22.—The One-Pipe Circuit System of Steam Heating.

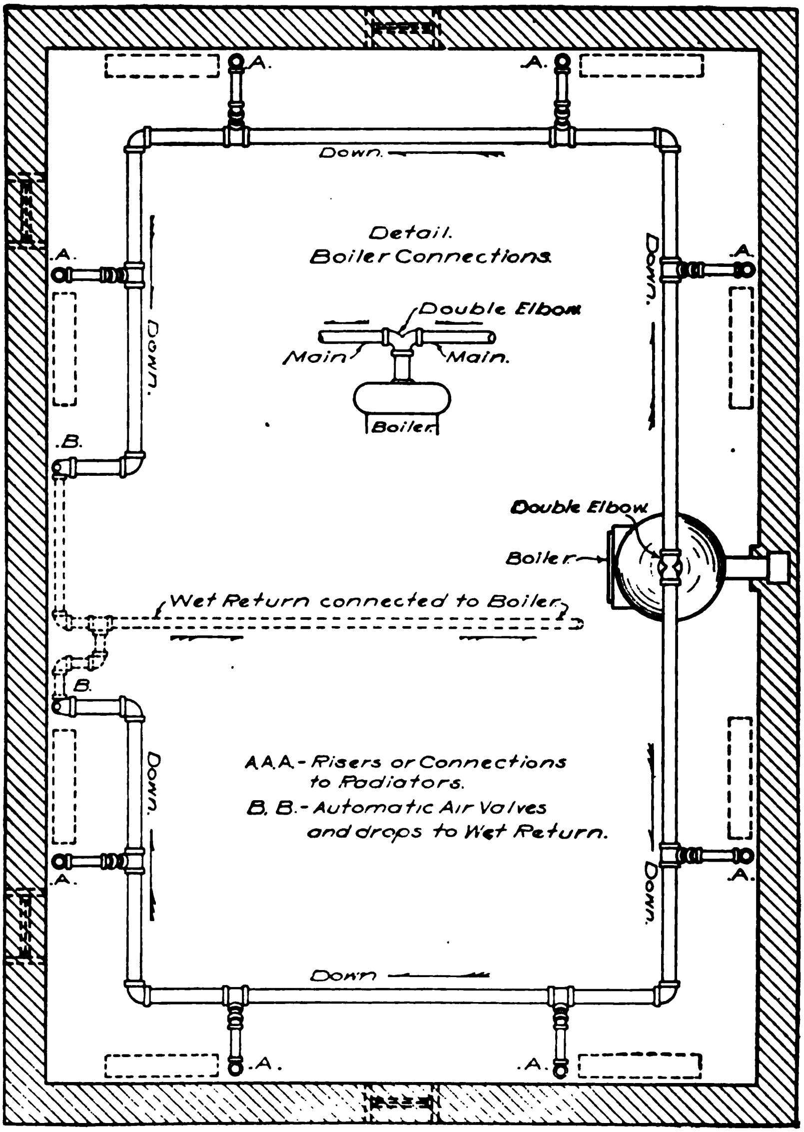


Fig. 23.—The Divided-Circuit System of Steam Heating.

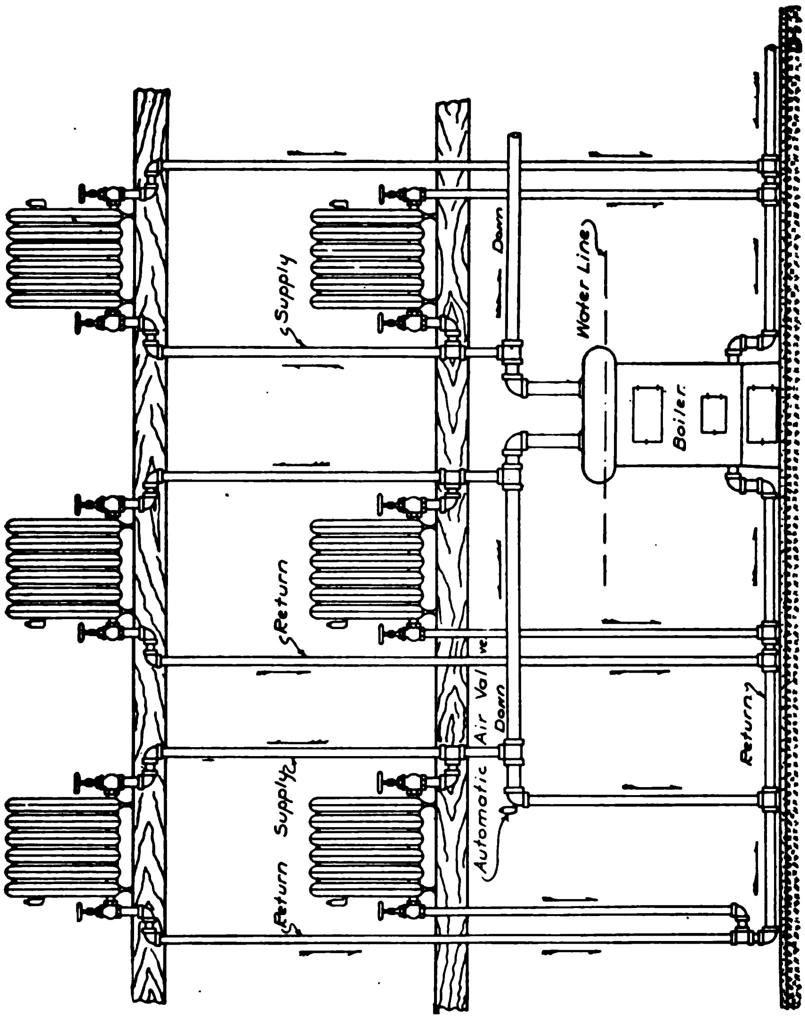


Fig. 24.—The Two-Pipe Method of Steam Heating.

of each should drop and be connected together below the water line, and the single or combined return should be returned wet to the boiler. Fig. 23.

22. Q. Describe the two-pipe system of steam heating.

A. The two-pipe system has a flow and return connection to

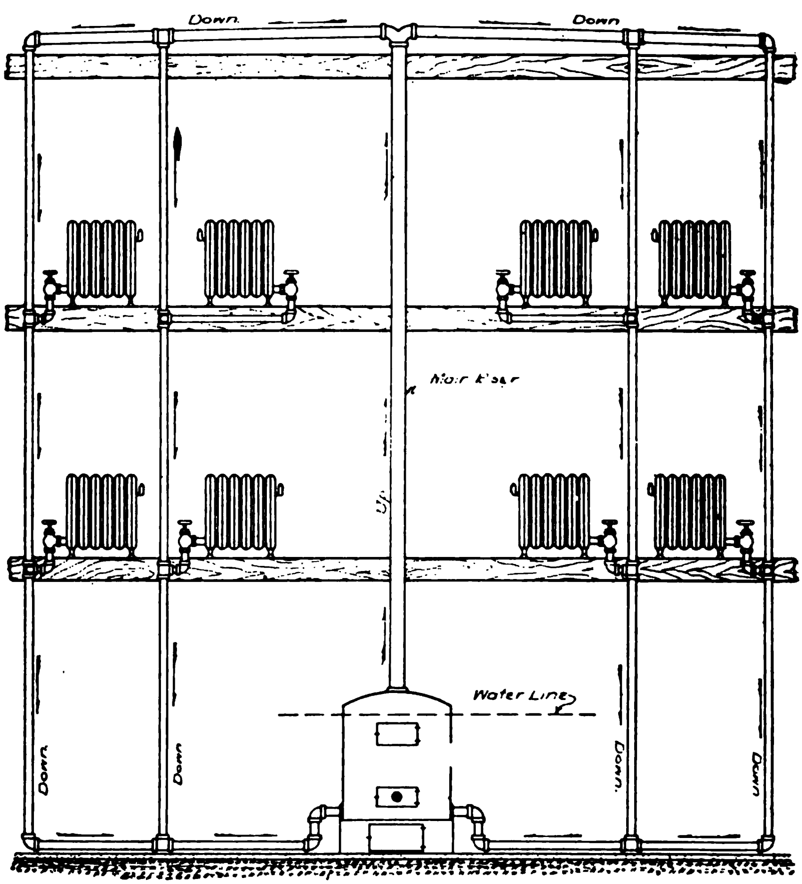


Fig. 25.—The Overhead or "Mills" System of Steam Heating.

each radiator or unit of radiation and a valve is placed on the connection at each end of the radiator.

The main of a two-pipe system is run in the same manner as for a circuit system; both it and the branch pipes are smaller than would be required for the one-pipe system as the supply pipes

accommodate the steam only, all condensation returning through the return pipes. Fig. 24.

23. Q. **Should the return pipes on a two-pipe system be wet or dry?**

A. Wet returns are preferable to dry returns for this system. The whole system of returns should drain or pitch slightly toward the boiler.

24. Q. **What is the overhead or Mills system of steam heating?**

A. The overhead or Mills system takes its name from the fact that the main is taken upward through the building to the attic or top of the system and all risers or connections to radiators are supplied by drop risers from above, all drips from risers and returns from radiators being connected into the main returns which are run in the basement. This system was adopted by John H. Mills, who was a prominent engineer and heating man in the early days of steam and hot water heating, and therefore is known as the Mills system. As all steam and water flow in the same direction there is little friction and the system is therefore considered very efficient and serviceable for any building to which it can be adapted. Fig. 25.

BOILER, RADIATOR, AND PIPE CONNECTIONS FOR STEAM HEATING.

1. **Q. What names are given to the various pipes which convey the steam from the boiler to the radiators or pipe coils?**

A. Mains, branches, risers and returns.

2. **Q. What is a steam main?**

A. By a steam main is meant those pipes which run horizontally from the boiler along the ceiling of the cellar or basement to convey steam to the various branches supplying the radiators or coils.

3. **Q. What is a branch or riser connection?**

A. The pipe leading from a steam main and connecting with a riser or a pipe supplying a radiator is called a branch or riser connection.

4. **Q. What is a riser?**

A. A pipe which extends vertically through one or more floors of the building from the end of a branch to the topmost radiator supplied.

5. **Q. What is a drop-riser and how installed and used?**

A. A drop-riser is used with an overhead system of steam supply; that is to say, a system on which the mains or distributing pipes are run at the top of the system. The drop risers extend down to the basement, feeding or supplying the steam to the radiators downward, the condensation from the radiators flowing downward with the steam.

6. **Q. What is a return pipe?**

A. A return conveys the water of condensation from the end of the main and other points of the system to the boiler and may be run above or below the water-line of the boiler. When run above the water-line they are designated as "dry" returns. When run below the water-line they are called "wet" returns, as they are always full of water below the water-line.

7. **Q. What is generally spoken of as a radiator connection?**

A. Radiator connections are the fittings and short pipes which connect the radiators to risers or branches.

8. **Q. How should steam mains be installed?**

A. The method of installation depends upon the character of

the work. The mains should always be carefully graded with sufficient pitch or fall to insure perfect drainage of the water of condensation which runs along the bottom of the pipe. They should extend around the basement a few feet from the foundation walls in a position convenient for connecting branches with the radiators or risers.

9. Q. What is meant by a "break" in a main or by the term "jumping the main"?

A. Structural conditions of the building may require, or when the run is long it may be necessary to make, a rise in the main to a higher level.

10. Q. How is the drainage taken care of under such a condition?

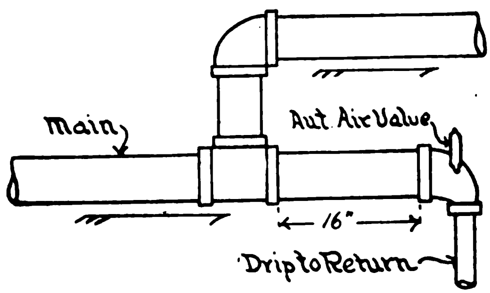


Fig. 26.—Method of Bleeding a Main When Raised to a Higher Level.

A. By a bleeder or drip from the bottom of the low point which should be of sufficient capacity to accommodate the greatest amount of condensation likely to accumulate at such a point, and the bleeder or drip should be connected into a wet return or a return below the water-line of the boiler. Fig. 26.

11. Q. What is meant by a bleeder or drip?

A. A small pipe connecting a trap or low point of the piping system with a wet return, and drips may be used at any point on the piping of a steam system to relieve accumulated condensation.

12. Q. What should be the size of the drip pipe or bleeder?

A. The size depends upon the size of the main and the length of the main drained by the drip. The following table gives the sizes necessary, it being supposed that a main of proper size has been installed.

DRIP PIPES FOR STEAM MAINS.

Diameter of Steam Main in Inches.	Length of Steam Main in Feet. 1 to 100	100 to 200	200 to 400	400 to 600
	Diameter of Drip Pipe in Inches.			
1¼ to 2	½	½	½	¾
3	½	¾	¾	1
4	¾	¾	1	1¼
5	¾	1	1¼	1½
6	1	1¼	1½	1½
7	1	1¼	1½	1½
8	1	1¼	1½	2
9	1	1¼	1½	2
10	1¼	1¼	1½	2

SIZE OF DRIPS FOR RISERS.

Square Feet of Radiation to Be Drained.		Diameter of Pipe in Inches.
0 to 50	—	¾
50 to 100	—	1
100 to 250	—	1¼
250 to 500	—	1½

This table is based on relieving the condensation from the main pipe only. If the condensation from the radiators enters the main the size of the drips should be increased accordingly.

13. **Q. What important matter should be provided for in the installation of all steam piping?**

A. Expansion of the pipes when heated, and contraction when cold. Piping installed in cold weather has contracted in length and when heated expands, the tremendous force of this expansion often cracking the fittings. Expansion or swing joints should be employed whenever necessary.

The expansion of wrought iron pipe under various conditions is as follows:

EXPANSION OF WROUGHT PIPE.

Temperature of Air when Pipe is Fitted.	Length of Pipe when Fitted.	Length of Pipe When Heated to 215 Deg. F. which corresponds to Atmosphere Pressure.		265 Deg. F. which corresponds to 15 Pounds Pressure.		297 Deg. F. which corresponds to 84 Pounds Pressure.		338 Deg. F. which corresponds to 100 Pounds Pressure.	
Deg. F.	Feet.	Feet.	Inches.	Feet.	Inches.	Feet.	Inches.	Feet.	Inches.
0	100	100	1.72	100	2.21	100	2.31	100	2.70
32	100	100	1.47	100	1.78	100	2.12	100	2.45
64	100	100	1.21	100	1.61	100	1.87	100	2.19

BOILER, RADIATOR, AND PIPE CONNECTIONS FOR STEAM HEATING

14. Q. How can a main be reduced in size without forming a trap or low place where condensation can lodge or without required for steam?

A By the use of reducing fittings tapped eccentric on the reduced end.

15. Q. What is meant by eccentric fittings or fittings tapped eccentric?

A. An eccentric fitting is a fitting tapped with the center of the smaller opening at such a point that the lower side of pipes screwed or adjusted to either end will be on the same level. The lower side of each pipe being on a level insures perfect drainage through the fitting without forming a pocket in which the water might lodge. Fig. 27 illustrates a tee with the small end tapped eccentric.

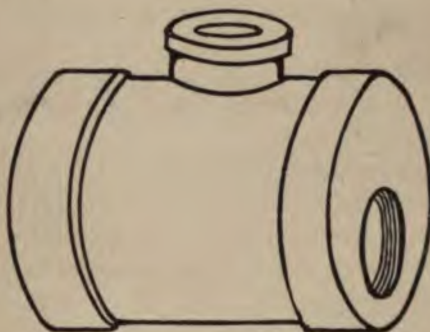


Fig. 27.—A Reducing Tee Tapped Eccentric.

16. Q. How are the branch pipes supplying radiators or risers connected to a main?

A. Two methods are in general use, the 90 degree connection and the 45 degree connection.

17. Q. What is meant by the term "90-degree connection"?

A. The tee on the main which supplies the branch is set with the side opening looking directly upward and a nipple and 90 degree elbow are used to connect the branch. Fig. 28.

18. Q. What is a 45-degree connection?

A. The tee on the main is set with the side opening looking upward at an angle of 45 degrees, and a nipple and 45 degree elbow are used for the branch connection. Fig. 29.

19. **Q. Is the use of a tee "bull-head," or used on the end of a pipe to divide the flow, considered good practice?**

A. A tee should never be employed in this manner as the friction and unequal division of the flow will harm the efficiency of the work. Fig. 30 shows the effect of such a connection, the arrows indicating the direction of the flow.

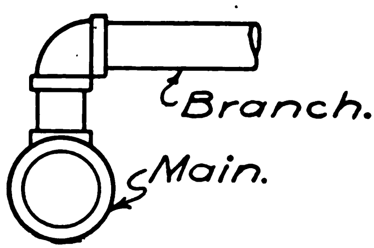


Fig. 28.—A 90 Degree Connection.

20. **Q. Which style of connection is preferable for use on a gravity steam job where the condensation from the radiators returns to the main?**

A. The 45 degree connection allows the water of condensation to return to the main without saturating the steam which occupies the upper part of the pipe and is therefore the best for one-pipe installations. Fig. 31 shows the condensation returning through a 90 degree connection, and Fig. 32 the condensation returning through a 45 degree connection.

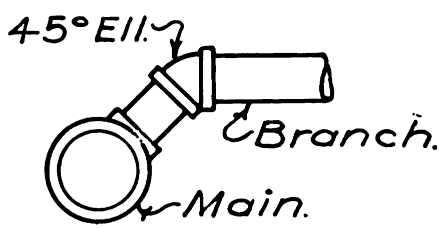


Fig. 29.—A 45 Degree Connection.

21. **Q. When is the use of the 90-degree style of connection permissible?**

A. On two-pipe work or in the event of the branch pitching away from the main.

22. **Q. What should be the size of the branch as compared with the riser or radiator connection fed by it?**

A. On one-pipe work the branch should generally be one pipe size larger than the riser or connection to the radiator in order to lessen the velocity of the steam in the branch and thus allow

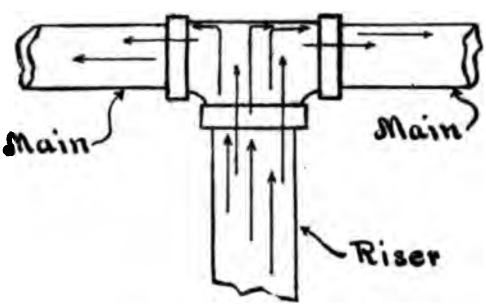


Fig. 30.—Effect of Using a Tee "Bull-Head."

the water of condensation to return in the bottom of the pipe against the pressure of the steam.

On two-pipe work the branch may be the same size as the riser or radiator connection as the drainage is made through a separate pipe.

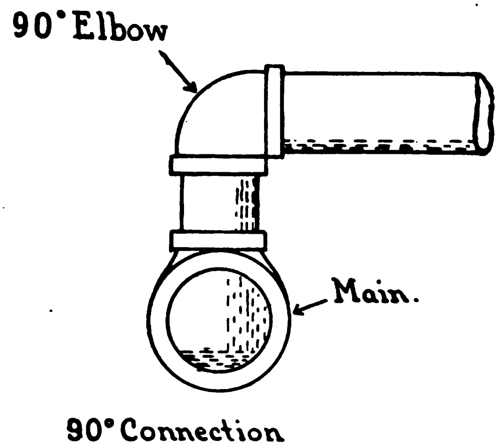


Fig. 31.—Condensation Returning Through a 90 Degree Connection.

23. Q. When a branch pitches downward from the main how is the water of condensation cared for?

A. By what is known as a heel drip at the base of the riser or

radiator connection; this drip pipe connecting with a wet return. Fig. 33.

24. Q. **What is known as a "swing" joint, and for what purpose is it used?**

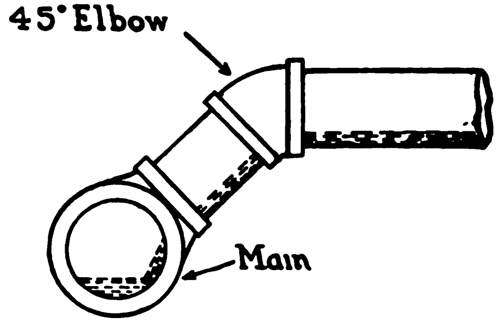


Fig. 32.—Condensation Returning Through a 45 Degree Connection.

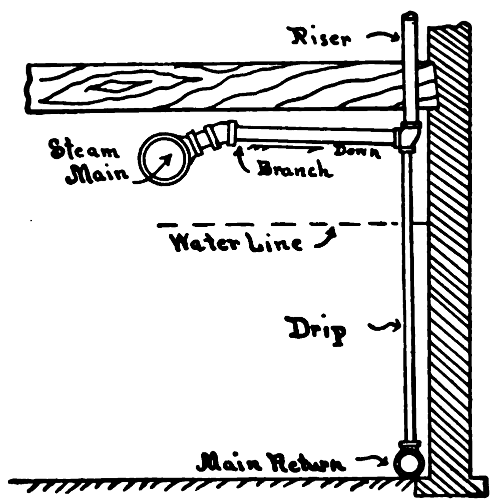


Fig. 33.—Method of Dripping a Riser.

A. A swing joint is made with two elbows and a nipple and is employed to allow a pipe to expand at right angles to its alignment. Fig. 34.

25. Q. **What is a "double swing" joint, and for what purpose is it employed?**

A. A "double swing" or "universal" swing joint is made by employing four elbows and nipples and when employed allows the piping to expand in any direction without breaking the fittings or without disturbing the alignment of the pipe. Fig. 35.

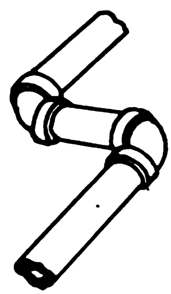


Fig. 34.—A Swing Joint.

26. **Q. How are radiators connected for the one-pipe system?**

A. But one valve is employed and the connection is made to one end of the radiator only; this pipe being of sufficient size to accommodate the supply of steam and the returning condensation.

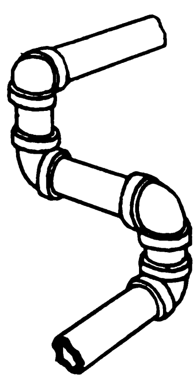


Fig. 35.—A Double Swing Joint.

Several styles of connections are used and those allowing for expansion are the best. Fig. 36 illustrates some of these.

27. **Q. How are radiators connected for the two-pipe system?**

A. A valve is used on each end of the radiator; that on the return being generally two sizes smaller than the supply valve. The

separate connection on the return end is made to drain the radiator of condensation. Owing to this fact the supply connection is made smaller than that employed on the one-pipe system. Several styles of two-pipe radiator connections are illustrated by Fig. 37.

28. Q. How are radiators connected when the overhead system of piping is employed?

A. They are usually connected as on an up-fed one-pipe system

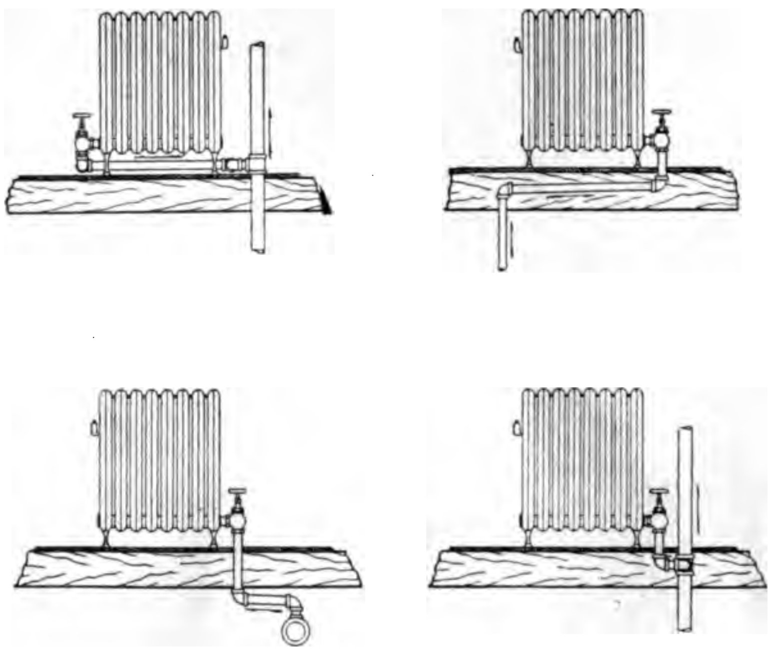


Fig. 36.—Methods of Connecting Steam Radiators, One-Pipe.

They may, however be connected with separate flow and return if the conditions of the work demand such a connection. Fig. 38. illustrates several methods.

29. Q. What causes "water hammer" or pounding in the piping of a steam heating system?

A. The presence of cold water at low points in the piping caused by imperfect drainage. These are commonly called "traps." The water of condensation lodging at such points cools when the supply of steam is shut off or the system allowed to cool and when a pressure of steam is again turned into the piping and passes the

pockets or traps the pounding occurs. This is due to the sudden condensation of the steam which produces a vacuum in the piping. The water endeavoring to fill this vacuum coming in contact with the steam produces a snapping or pounding as of hammering on the piping.

30. Q. **Should return mains be run wet or dry, that is, above or below the water-line of the boiler?**

A. The method of running the returns depends upon the character of the installation. They may be either wet or dry.

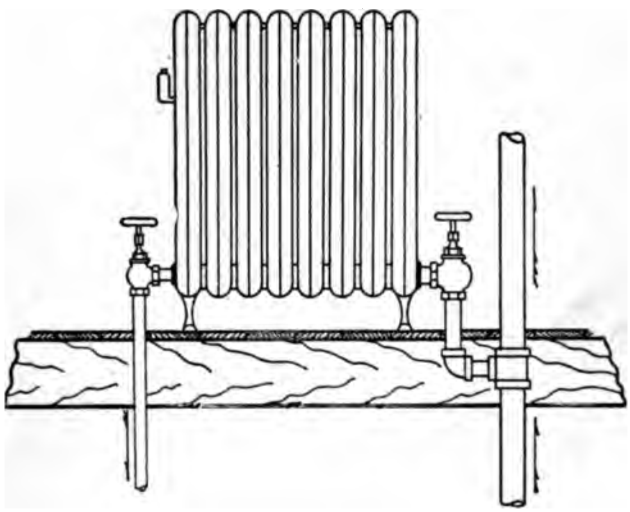


Fig. 37A.

A dry return should have no other return pipes connecting into it. If two or more returns are to be connected together the connection should be made below the water-line. For two-pipe work the wet return is preferred.

31. Q. **How can this be accomplished when a portion of the cellar or basement is not excavated?**

A. By the employment of a false water-line to flood the return piping.

32. Q. **How is a false water-line created?**

A. By trapping the main return at a point sufficiently high to keep the pipe and connections full of water. The trap should be

so arranged that it may be drained when desired. This is accomplished by making a connection from the bottom of the trap to the wet return and placing a valve on the connection. A balance or equalizing pipe should connect the top of the loop with the steam main. Fig. 39.

33. **Q. What difference in height should be maintained between the end of a main or dry return and the water-line of the boiler?**

A. Where pipes of generous size are employed a distance of 14 inches is considered sufficient although under certain conditions

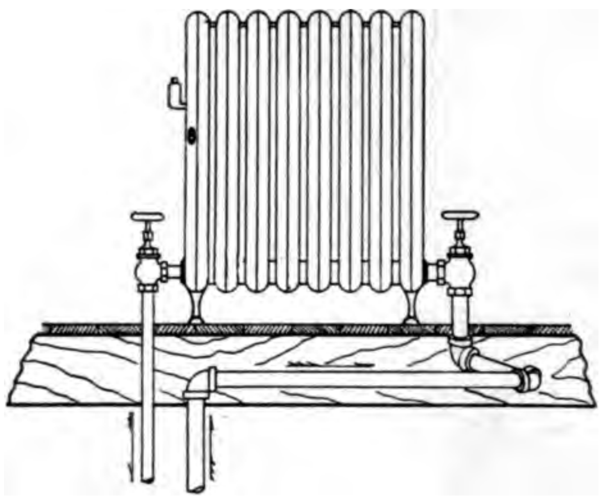


Fig. 37B.

it may be less or must be greater. Many heating engineers demand a distance of 30 inches between the end of main and the water-line. Fig. 40.

34. **Q. Why is a distance of 14 inches between the end of main and the water-line necessary?**

A. Tables based upon accepted practice giving sizes of mains for various amounts of radiation are conditioned upon a pressure of 2 pounds to 5 pounds at the boiler, and a low velocity of the steam with a drop in pressure at the end of the line of from 1/4 to 1 pound. The difference in pressure (occasioned by the friction due to the length of the main and fittings on the same) causes the water in the return to rise above the level of the water in the boiler and

this difference in height of water is provided for by keeping the end of the main at a sufficient height above the water-line.

The reason of the rise of the water in the return is not always understood. When the fire is started in the boiler the water in the system stands level. As a pressure is created on the boiler it lowers the level of the water in the boiler and raises it in the return, the amount of rise being conditioned by the pressure of steam at the end of the main.

Supposing the pressure at the boiler is two pounds and at the

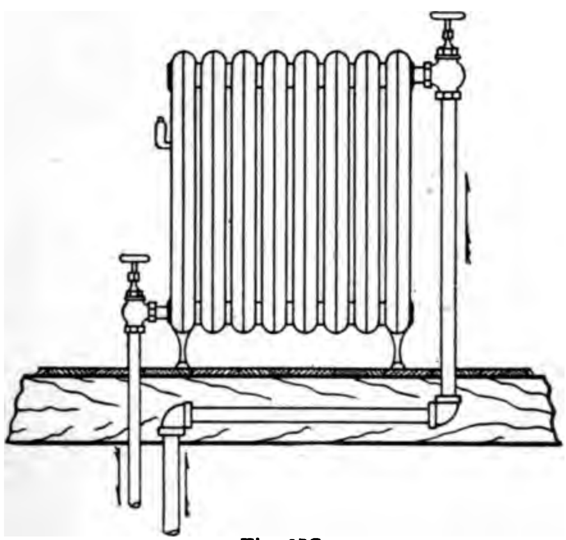


Fig. 37C.

Fig. 37-A-B.—Methods of Connecting Steam Radiators, Two-Pipe.

end of the main one pound, a difference of a pound. The head of water equal to a pound pressure is 26.67 inches; therefore, the water in the return at the end of the system would stand 26.67 inches above the water in the boiler. Small mains increase this difference and large mains reduce it, therefore generous size mains should be used.

35. Q. Are rules given for determining the sizes of mains for low pressure steam heating?

A. Several very good rules are given but it should be stated that no two heating engineers agree exactly in their ideas of size. Baldwin has a simple rule as follows: To find the number of

square feet of heating surface a steam main will supply, square the diameter of the main in inches and multiply by 100. Example: A 2-inch main 50 feet in length. How many square feet of radiation will it supply?

2 × 2 (2 inches squared) × 100 = 400 square feet.

To find the size of steam main required to supply a given amount of radiation, point off two places in the amount of radiation given and find the square root of the remainder. Example: To supply 400 square feet of radiation with a main 50 feet long—4.00 (two places pointed off) = 4.

The square root of 4 is 2 (2 × 2 = 4), therefore a 2-inch main is required.

An increase in the length of a main or in the number of fittings used increases the frictional resistance to the flow of steam and demands an increase in the size of it.

SIZE OF STEAM MAINS, ONE-PIPE SYSTEM.

Direct Radiation Sq. Ft. of Htg. Surface Supplied.	Length of Main in Feet.									Size of Return
	20	40	80	100	200	300	400	600	1000	
	Diameter of Pipe in Inches.									
150	1½	1½	1½	1½	2	2½	2½	3	3	1
300	2	2	2	2	2½	3	3	3	4	1¼
450	2	2½	2½	2½	3	3	3½	3½	4	1¼
900	2½	2½	3	3	3½	3½	4	4	4½	1½
1200	3	3	3½	3½	4	4	4½	4½	5	2
1600	3½	4	4	4	4½	4½	5	5	6	2
2000	4	4	4½	4½	5	5	6	6	7	2½
2500	4	4½	4½	5	6	6	6	7	8	3
4500	5	5	5	6	7	7	7	8	9	3
6500	5	6	7	7	8	8	8	9	10	3½
9000	6	7	8	8	9	9	9	10	11	4
11,000	7	8	8	9	10	10	10	11	12	4½

Note: Size of returns as given in the table for "Wet" returns. For "Dry" returns one size larger pipe should be used.

36. Q. How is the expansion of the piping of a steam job provided for?

A. By the use of expansion hangers on the main and by swing or expansion joints on mains or risers. Mains supported on expansion hangers can move in either direction as the pipe expands or contracts.

37. Q. In the case of risers, in what direction is the expansion, and how can they be supported to allow for it?

A. The expansion of a riser is either up or down. For an ordinary two or three story job this expansion may be provided for by a swing joint at base of riser. Fig. 41. For a riser of considerable length the expansion may be directed both upward and downward by anchoring the riser near the middle of its length. Fig. 42.

38. Q. How can a riser be supported without the employment of hangers?

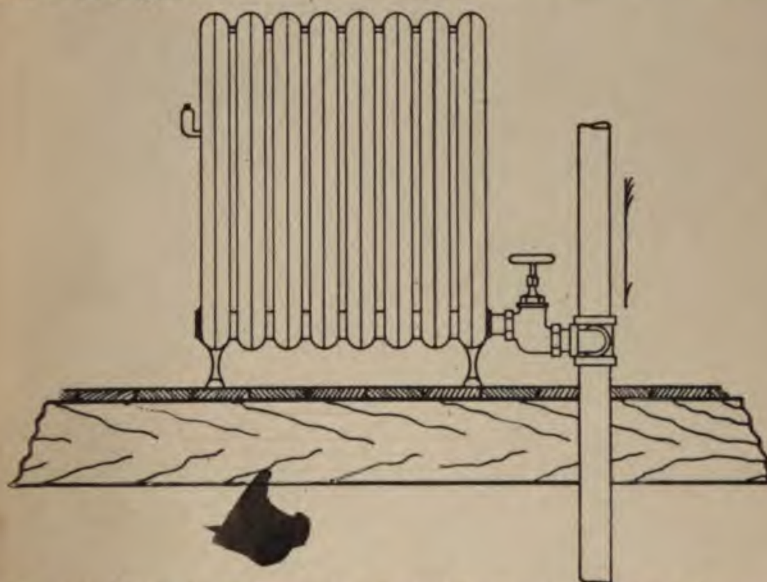


Fig. 38.—Method of Connecting Steam Radiators, Overhead System.

A. By using a coupling on the riser which rests upon a floor plate. The riser is cut to such a length that in coupling on the extension the bottom of the coupling will rest upon the floor plate which is a neat and practical method to employ. Fig. 43.

39. Q. What should be the area of the riser or risers out of the boiler as compared with the area of the main or mains?

A. The risers out of boiler should be from 30 to 50 per cent. greater in area than the mains which they feed. Fig. 40.

40. Q. What is the reason for employing boiler risers or steam connections so much greater in area than the mains?

A. Because it is advisable that the initial velocity of the steam

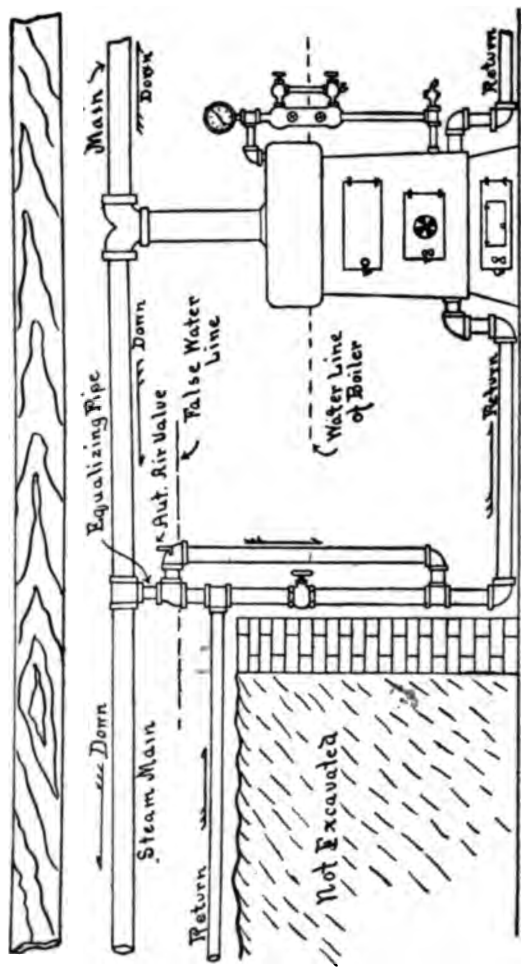


Fig. 39.—Method of Establishing False Water-Line.

as it leaves the boiler should be as much below the velocity of the steam in the main as possible in order to prevent the lifting of the water into the main.

41. **Q. What would be the result of making risers and mains of equal area?**

A. The velocity of steam in a vertical pipe is so much greater than in a horizontal pipe that under conditions of heavy firing or the presence of a little oil or dirt in the boiler a steady water-line

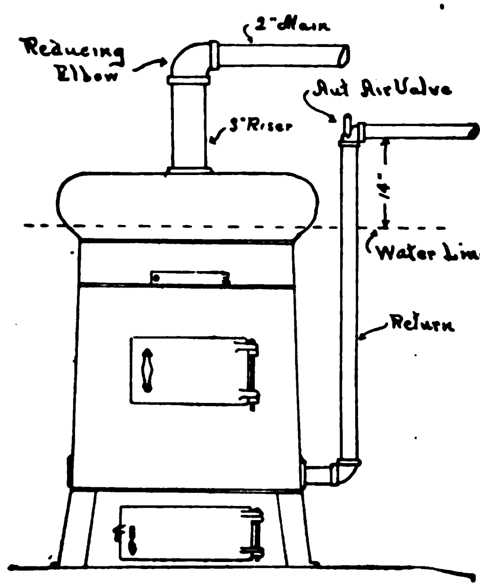


Fig. 40.—Showing Difference of 14 Inches in Water Line.

could not be maintained as the steam will carry water into the main and under certain conditions siphon the water from the boiler.

42. **Q. Is the employment of a steam header on a boiler advisable?**

A. The use of a header is good practice, particularly on sectional boilers having several steam outlets, and when properly constructed will prevent siphonage of the water into the mains and also provides for every movement of the pipe in expanding and contracting. A header filters the steam supply and insures dryer steam in the heating system. Fig. 44 shows an elevation of a steam header properly connected and Fig. 45 a plan of the same.

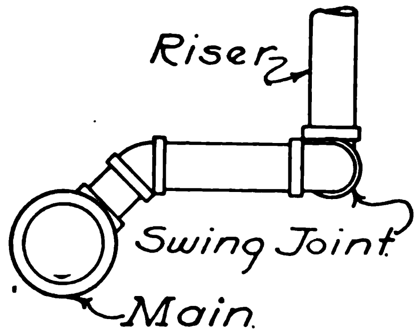


Fig. 41.—A Swing Joint at Bottom of Riser.

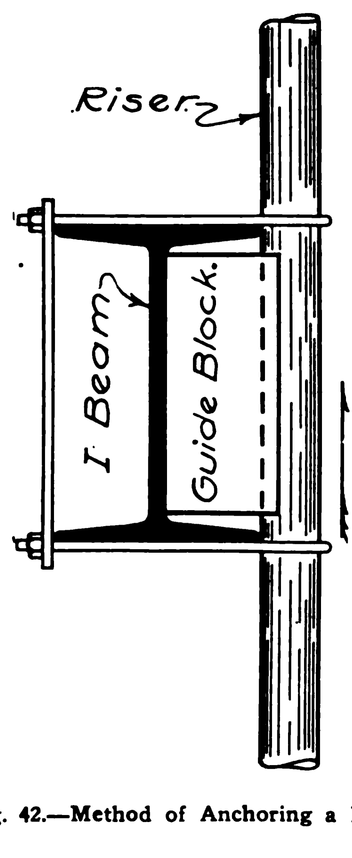


Fig. 42.—Method of Anchoring a Riser.

43. **Q. What is an equalizing pipe, and for what use is it employed?**

A. When two or more boilers are connected together or in battery a pipe connection between the steam space of each boiler, with a drip connecting to the return header, equalizes the pressure in the boilers and maintains an equal water-line in each. A large drip pipe connecting the header of a boiler with the return is also known as an equalizing pipe. It drains the condensation from the

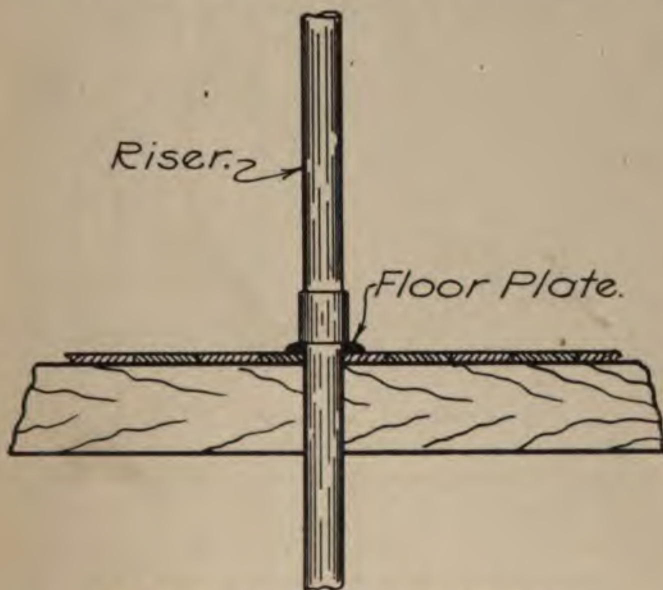


Fig. 43.—Riser Supported on Floor Plate.

header and equalizes the pressure on the return. An equalizing pipe of this character is shown in the illustrations, Figs. 44 and 45.

44. **Q. What is a return header, and for what purpose is it used?**

A. When two or more boilers are connected together it is advisable to run a pipe across the rear of the boilers and connect the return openings of each boiler to it. This is called a return header and its use permits an equal distribution of the return water to each boiler. The return pipes from the heating system may then be connected to this header at any convenient point. Fig. 46. On work requiring a single sectional boiler of large size it is advisable to use a return header.

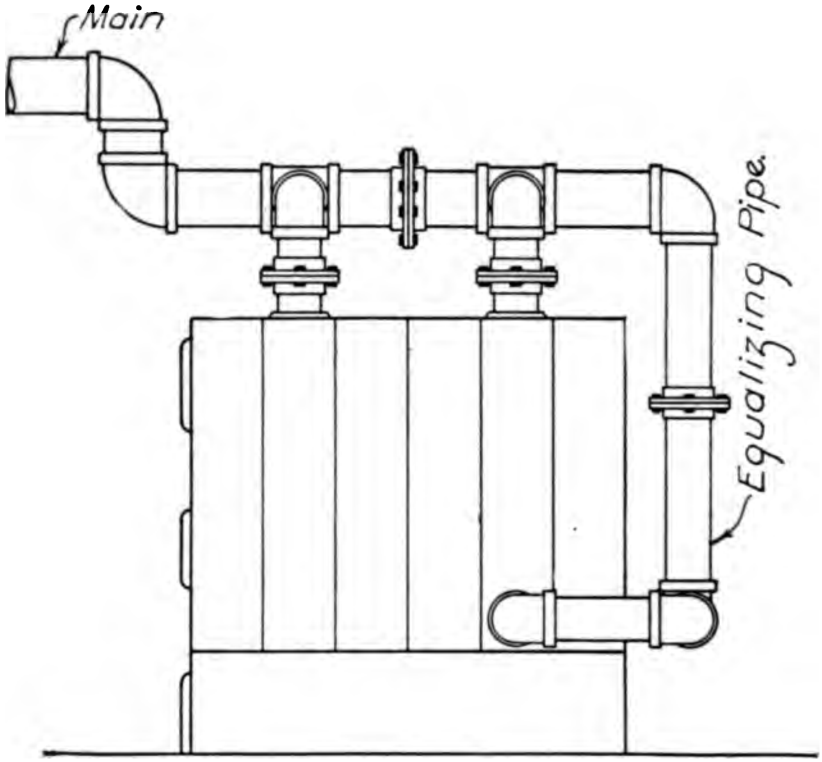


Fig. 44.—Showing Steam Header on Boiler.—Elevation.

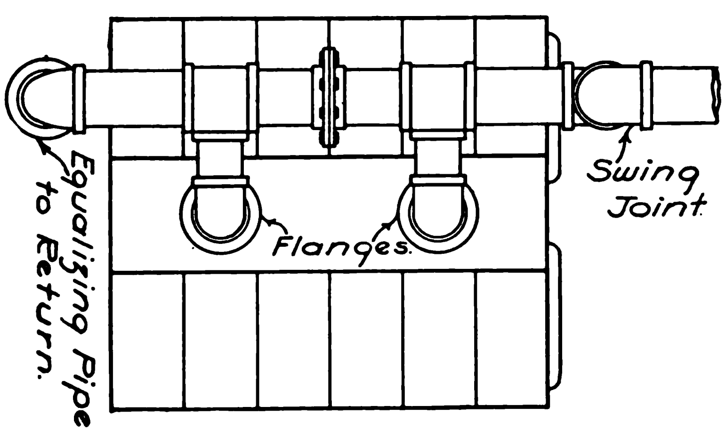


Fig. 45.—Showing Steam Header on Boiler.—Plan.

BOILER, RADIATOR, AND PIPE CONNECTIONS FOR STEAM HEATING

45. **Q. When it is necessary to pass over a beam with the main of a circuit job, how can the condensation be taken care of without bleeding or dripping the main?**

A. By a drainage connection from the main on one side of the beam to the main on opposite side as shown by Fig. 47. The condensation will rise to its level on the low side and continue along

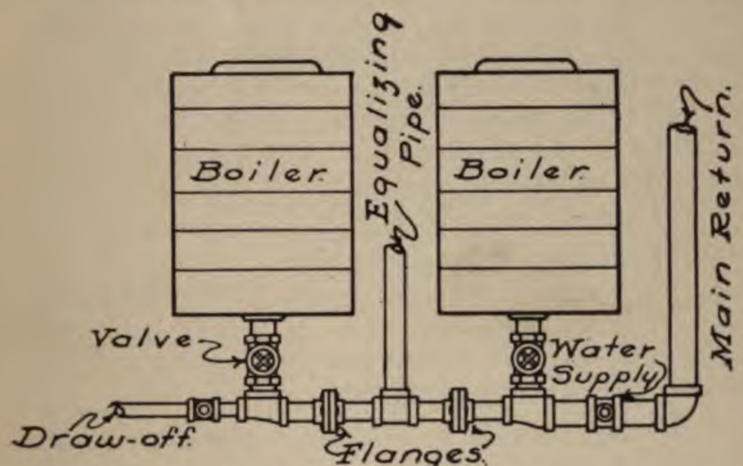


Fig. 46.—Return Header on Boiler.

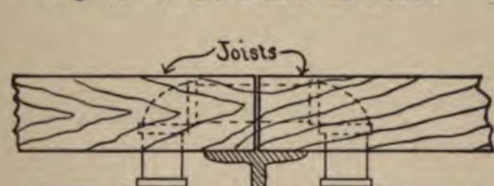


Fig. 47.—Method of Crossing I Beam With Main.

the bottom of the main. The small pipe for conveying the condensation under the beam should be of sufficient size to pass all water and it should be carefully graded to pitch with the main. Provisions for draining the pocket may be made if desired by using a plugged tee at the low end in place of an elbow or inserting a drainage cock at this point.

HOT WATER HEATING.

1. **Q. How are hot water heating systems classified?**

A. As open systems—meaning systems which are open or vented to the atmosphere—and closed systems, which are systems closed to the atmosphere by sealing the outlet of the expansion tank. The latter is sometimes designated as a "pressure" system. There are several methods of installing the piping for either system and each of these methods is frequently called a "system" although they differ only in the manner of installations, the principle of circulation remaining the same.

2. **Q. What type of hot water apparatus was the first to be employed commercially?**

A. The closed or high pressure system. This was first in general use in England and was known as the Perkins system from the fact that a firm of foundrymen and engineers named Perkins and Son developed and used this system.

3. **Q. When did hot water heating come into general use in the United States?**

A. Not until the period 1875 to 1885, although hot water heat had been extensively used in Canada for several years previous to 1875.

4. **Q. What system of piping was employed at this time?**

A. The open tank system was the method ordinarily used although the closed or pressure system had also been employed to some extent, but had never met with popular favor.

5. **Q. What advantages are claimed for the closed system?**

A. The ability to carry a higher temperature of the water without boiling than is possible with an open system. Water in an open vessel at sea level boils at a temperature of 212 degrees, but when confined increases in temperature according to the pressure carried on the system. Smaller piping, fittings and valves are used on a pressure system than are required for an open tank system.

The following table gives the temperatures of hot water from the boiling point (the limit of temperature in an open system) to a pressure of 25 pounds—a temperature of 269.1 degrees.

6. Q. What method is commonly employed to seal a hot water system and what precaution is it necessary to provide for safety?

A. A safety valve is placed on the outlet to the expansion tank. This safety valve is set to operate at a nominal pressure, possibly 10 pounds. This valve should be examined frequently to see that it is in working order and operative at the pressure at which it is set. Should the valve stick or fail to operate an excess of pressure might accumulate which would rupture the apparatus and cause damage to the property and possibly endanger the lives of those occupying the building in which the apparatus was installed.

TABLE OF TEMPERATURES AND PRESSURES.

Pressure per Square Inch.	Temperature.	Pressure per Square Inch.	Temperature.
0 lbs.	212 deg.	4 lbs.	225.6 deg.
½ "	214.5 "	4½ "	227.1 "
1 "	216.3 "	5 "	228.5 "
1½ "	218 "	7½ "	235.1 "
2 "	219.6 "	10 "	241. "
2½ "	221.2 "	15 "	251.6 "
3 "	222.7 "	20 "	260.9 "
3½ "	224.2 "	25 "	269.1 "

7. Q. Why is the open tank system preferred to the pressure or closed system?

A. It is safer and more readily adapted for ordinary hot water installations. It being open to the atmosphere is absolutely safe under all conditions. It is also more readily attended or operated by an inexperienced person.

8. Q. What causes hot water to circulate through an open tank gravity system?

A. The principles of hot water circulation are now very generally understood. A cubic foot of water at a temperature of 40 degrees weighs 62.42 pounds. A cubic foot of this water when heated to 180 degrees weighs but 60.55 pounds. In heating the water it expands and becomes lighter, increasing in volume about 5 per cent. when heated to 180 degrees. When confined in a vessel and heated it will expand upward.

Hot water circulation is the result of the law of gravitation. In a hot water system as the water in the boiler expands and becomes lighter the colder water returning to the boiler, which is denser and heavier, crowds the lighter, heated water upward, thus estab-

lishing a circulation through the system of piping and radiators; therefore it is the difference in weight or specific gravity between the flow and return columns *above the source of heat energy* that causes the circulation of the water, and the greater this difference in weight the greater will be the velocity of the circulation.

9. **Q. Is the open tank system operated under a pressure?**

A. Yes, although it is not generally thought of as being operated under pressure. The average open tank system is operated under a pressure of from 15 to 20 pounds; this pressure is due to the height of water in the system.

10. **Q. How many methods or systems of low pressure or open tank hot water installations are in general use?**

A. Three; the regular two-pipe system, the overhead system and the circuit or single main system.

THE TWO-PIPE GRAVITY SYSTEM OF HOT WATER HEATING.

1. Q. Describe the regular two-pipe system.

A. The two-pipe system of hot water heating consists of a series of flow pipes leading from the boiler to the various radiators or heating surfaces and a corresponding or companion set of return pipes leading from the radiators to the boiler. Formerly, or during the period when hot water was first used, it was customary to run separate flow and return pipes to each large radiator or group of radiators with the result that frequently as many as eight or ten separate flow and return pipes were employed. At the present time, out one or two main flow and return pipes are to be found on an average sized job, each of the flows serving to supply a number of radiators, the pipes being installed sufficiently large for the purpose. The circulation to each radiator is guided by a certain character of pipe connection intended to equalize the flow and divide it equally among the several radiators supplied.

The general design of this system is shown by Fig. 48.

2. Q. Is the main run full size to the end of it or to the last radiator supplied?

A. No. It is customary to reduce the size of the main as the branches are taken off or supplied. The main should not be reduced too rapidly as the water is colder and the circulation slower as the end of the line is approached.

3. Q. What conditions the size of piping required for mains or branches?

A. The area of the valves on the radiators supplied. The area of the main flow should always equal or exceed the combined areas of all radiator valves and in reducing as the various branches and radiators are connected the area should remain sufficient to supply all radiators ahead of or beyond the point of reduction.

4. Q. What should be the area of the main at the end or point where the last radiator is supplied?

A. At least one, and preferably two, pipe sizes larger than the vertical pipe leading to the radiator valve.

5. Q. How should the branches be taken from the main on a two-pipe gravity system?

A. The branches which supply risers leading to upper floors

should be taken from the side of the main. There is always a tendency for the flow of hot water to seek the highest point and branches to risers if taken from the top of the main would rob the circulation to first floor radiators. When the side connection is

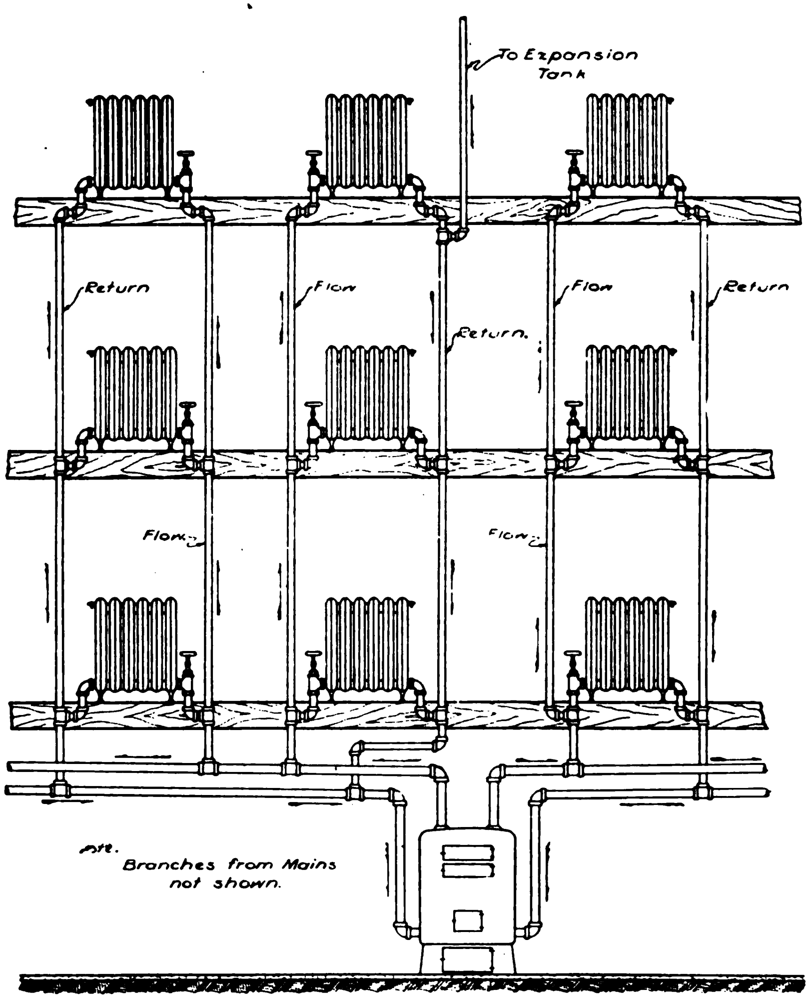


Fig. 48.—The Two-Pipe Gravity System of Hot Water Heating.

used the first water heated (which always occupies the top part of the main) passes along to the connections of first floor radiators, and the branches to risers do not receive their supply until the hot water in the main has filled it sufficiently to feed through the side connection. Fig. 49.

THE TWO-PIPE GRAVITY SYSTEM OF HOT WATER HEATING

6. Q. How should the branches to first floor radiators be connected?

A. From the top of the main with a 90 degree ell or at an angle of 45 degrees as illustrated by Fig. 50. The 45 degree connection is preferred.

7. Q. When it is necessary to divide the main into two flows leading in opposite directions, what type of fitting should be employed?

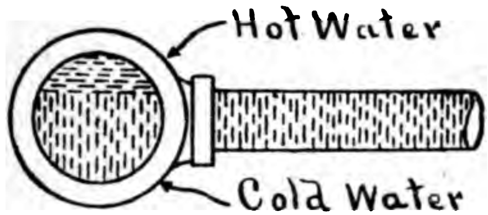


Fig. 49.—Branch Taken From Side of Main.

A. A double elbow. A tee should never be used for this purpose on account of the friction at this point. The double elbow divides the flow evenly with the least friction possible. Fig. 51.

8. Q. What position does the return main occupy?

A. The return main follows the direction of the flow and is usually placed directly by the side of the flow (within a distance of

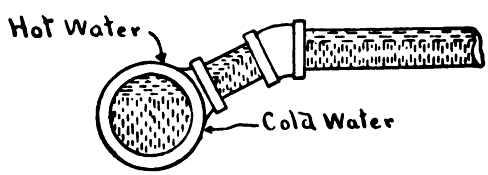


Fig. 50.—Branch Taken From Main With 45 Degree Connection.

from eight to twelve inches) until the boiler is reached, when there is a vertical drop to connect into the return opening of the boiler.

9. Q. How are return branches from first floor radiators connected into the return mains?

A. On the side in order that the return circulation from one radiator or riser will not block the return from another should the temperature of the water in them be unequal.

10. Q. **How are return branches from risers to upper floors connected to main?**

A. Into the side of the bottom with a 45 degree connection.

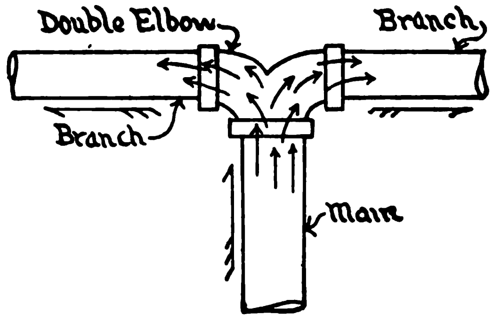


Fig. 51.—Double Elbow Used to Divide Main.

11. Q. **How are riser connections to upper floors made from a riser supplying a second floor radiator?**

A. The radiator on the second floor should be connected from

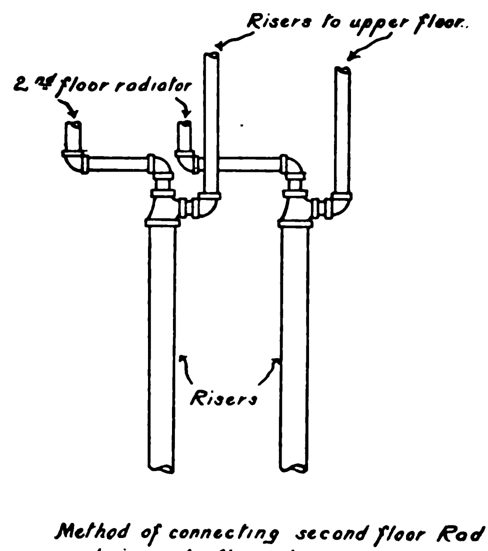


Fig. 52.—Method of Connecting Hot Water Risers.

the top of the riser to the second floor and the risers supplying radiators to upper floors should be taken from the side of the riser supplying the second floor below the connection to the radiator. Fig. 52.

THE TWO-PIPE GRAVITY SYSTEM OF HOT WATER HEATING

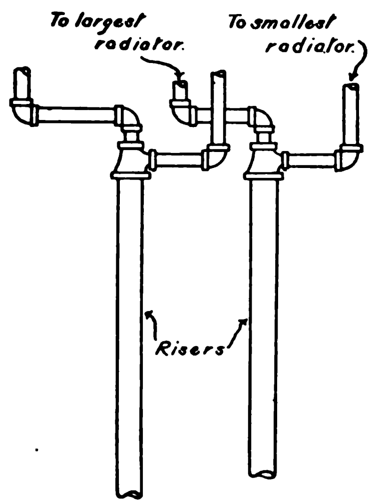
12. **Q. When two radiators on the same floor are supplied from a single riser how should they be connected?**

A. The connection from the top of the riser should supply the larger radiator. The side connection from the tee on riser should supply the smaller radiator. Fig. 53.

13. **Q. With both radiators of equal size how should they be connected?**

A. Generally by reducing the size of the pipe connection to the radiator connected from the top of the riser.

14. **Q. In cutting and threading the piping what precaution should be observed?**



Method of connecting two radiators on same floor from single riser.

Fig. 53.—Method of Connecting Hot Water Risers.

A. The burr left. on the pipe by the cutting tool should be removed by reaming. On small pipes the burr left by the cutting tool will reduce the pipe one size and cause sufficient friction to seriously interfere with the velocity of the flow of water through the pipe.

15. **Q. What provision is made for the expansion of the water in a hot water system to prevent overflowing when heated?**

A small tank called an expansion tank is usually provided; it is located at the top of the system or above the highest radiator and from the bottom of the tank a pipe called an expansion pipe

is connected to the return from one of the highest radiators or the return at the boiler; from the top of the tank a vent pipe leads to the atmosphere.

16. Q. What expansion of the water takes place in an ordinary hot water system?

A. Water as used in the ordinary hot water heating apparatus expands about 1-24 or 1-25 of its volume.

EXPANSION TANKS.

No.	Size—Inches.	Gallons—Capacity.	Square Feet Direct Radiation Supplied.
0	10 x 20	8	250
1	12 x 20	10	300
2	12 x 30	15	500
3	14 x 30	20	700
4	16 x 30	26	950
5	16 x 36	32	1300
6	16 x 48	42	2000
7	18 x 60	66	3000
8	20 x 60	82	5000
9	22 x 60	100	6000

17. Q. What size of expansion tank should be used for the open tank hot water system?

A. Based upon the expansion of water as stated above the following table of sizes of expansion tanks will be found sufficient for general use.

THE CIRCUIT SYSTEM OF HOT WATER HEATING.

1. **Q. Describe what is known as the circuit system of hot water heating.**

A. The circuit system or as it is sometimes known, the single main system, is installed with a single main supply pipe which makes a circuit of the basement of the building in quite the same manner as the main of a single or one-pipe steam system. This main acts as both flow and return. The hottest water in a hot water main is always at the top of the main, the cooler water at the bottom, and on this fact the principle of the circulation of a circuit system is based—two bodies of water at different temperatures flowing through the same pipe. The main rises from the boiler to a point as high as desired and makes a circuit of the basement pitching downward from the boiler or up to a point which is called the high point of the main and from this high point whether it is immediately above the boiler or at some other part of the system the expansion tank is connected in order to relieve the air in the system from the high point. The radiators are connected with a flow and return branch, and risers are connected in the usual manner. Flow branches are connected from the main at the top and return branches enter the main at the bottom or at the side of the bottom. Fig. 54.

2. **Q. What special fittings can be employed to advantage on the main of a circuit system?**

A. There are several special fittings manufactured which assist in dividing the flow and return circulation; among these are the Eureka Fitting shown by Fig. 55, and the Phelps Single Main Tee shown by Fig. 56.

The Eureka fitting has a double compartment which allows the return water to enter the fittings and which joins the water in the main through an opening at the bottom of the fitting without interfering with the flow of hot water from the same. The Phelps single main tee is a tee with an extra outlet which is located at the side of the bottom which is used for the return connection. Either of these special fittings assists in separating the flow and return and in increasing the circulation through the system.

3. **Q. What should be the size of the main for a circuit or single main system?**

A. As a rule the size of the main should be estimated by considering the size of the radiator valves or radiator connections. The size of main is also dependent somewhat upon the length of the circuit. If in making the circuit of the basement a main of considerable length is necessary it is well to increase the size of main owing to the fact that the temperature of the water in each leg of the main is considerably reduced, that is to say, the water in the last leg of the circuit is considerably cooler than that in the main as it leaves the boiler.

4. Q. In proportioning the radiation for a single main system what fact must be considered?

A. The fact mentioned above as to the cooling of the water in the main. The radiation attached or supplied from the last leg of

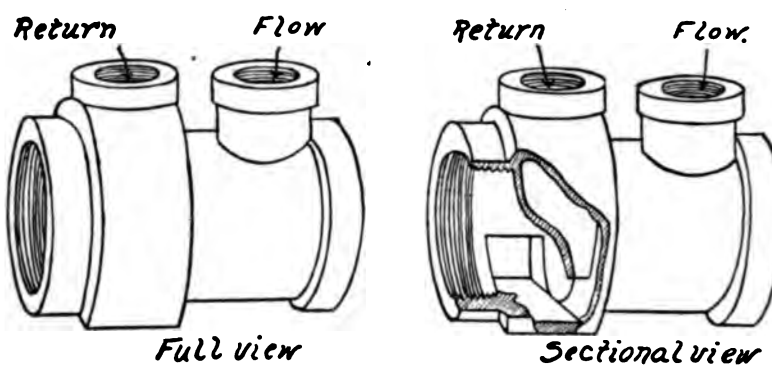


Fig. 54.—The Eureka Fitting.

the main should be figured quite a little stronger than that connected nearer to the boiler.

5. Q. Is the single main or circuit system an open tank system?

A. It may be the open tank or the closed tank system. Probably the best results are obtained where the water is circulated under a slight pressure as the rapidity of the circulation when used as a pressure job increases the temperature of the water sufficiently to reduce the amount of loss in making the circuit of the building.

6. Q. What should be the pitch of the main for a circuit system?

A. The main should have the usual pitch of ½ to 1 inch in each 10 feet of length.

7. **Q. How are the branches run and the risers and radiators connected for this system?**

A. The same as for the regular two-pipe system.

8. **Q. What size of pipe should be employed for the main of a circuit system?**

A. The size of main is conditioned largely by circumstances such as the square feet of radiation supplied, the length of the circuit and the number of radiator connections.

The following table shows what may be considered as an average

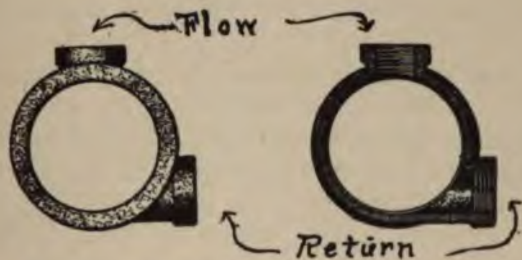


Fig. 55.—The Phelps Single Main Tee.

amount of radiation which can be supplied by a circuit main of given size:

SIZE OF MAINS FOR CIRCUIT SYSTEM.

Size of Main.	*Direct Radiation Supplied.*
2 inch	175 to 250 square feet
2½ inch	300 to 450 square feet
3 inch	500 to 650 square feet
3½ inch	700 to 900 square feet
4 inch	1,000 to 1,500 square feet
5 inch	1,600 to 2,200 square feet
6 inch	2,400 to 3,000 square feet

THE OVERHEAD SYSTEM OF HOT WATER HEATING.

1. **Q. Describe the overhead system of hot water heating.**

A. The overhead system of hot water heating as its name implies is a method of supplying hot water to radiators located on various floors from a system of piping which is run overhead at the top of the building. The mains may be suspended from the ceiling of the top floor or be run through an attic or loft if such is available. Fig. 56.

A single large pipe riser (or risers) is run in the most convenient manner to the attic or top of the building and there is distributed through mains and branches to risers dropping down to the basement through the various floors supplying the various radiators connected to each riser.

The top of the main riser is the high point of the system and from this point all pipes pitch downward. The top of the riser being the high point of the system the expansion tank is connected from this point in order to relieve the air in the system when filling or which may accumulate later at this point.

2. **Q. What advantage has the overhead system of piping over the ordinary two-pipe up-fed system?**

A. As the supply riser or risers leading to the upper or top floor are the largest pipes on the system the water rises to the high point without the amount of friction usually found in several smaller pipes and in its descent through several smaller pipes supplying the radiators the friction is largely eliminated or taken care of by the weight of the water in the system which increases the circulation through the pipes and radiators. The circulation in an overhead system is much more rapid than is found in the open tank up-fed system and the results obtained from a given amount of fuel burned are very much greater than those obtained with the up-fed system. The use of this method also lacks one of the objectionable features of the regular two-pipe system; namely, the constant trouble from air accumulating in the upper radiators. The overhead system is installed without the use of air valves as all pipes pitch upward towards the top of the main riser and from this point all air is expelled to the tank, rendering the use of air valves unnecessary.

3. Q. What is the method of supplying the branches from the various mains at the top of the system?

In order to prevent air pockets which would interfere with circulation all branches are taken from the bottom of the main with a 90 degree or a 45 degree elbow; the 45 degree connection as shown by Fig. 57 is preferred.

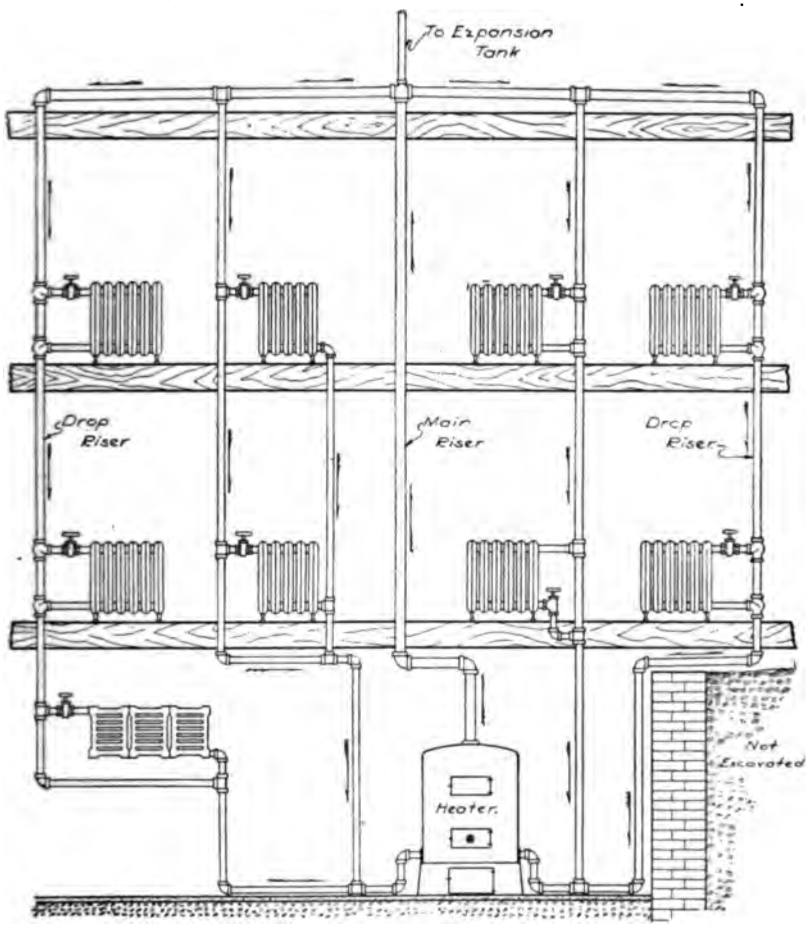


Fig. 56.—The Overhead System of Hot Water Heating.

4. Q. What method is used to support the large risers carrying the supply of heated water to the top of the system?

A. As the main riser or risers leading to the upper floor are the largest pipes on the work and contain the greatest weight of water it is difficult to support the same with ordinary hangers, and

it is good practice to use a fitting at the bottom of the riser known as a base elbow which should rest on a brick or cement pier supporting the riser.

5. Q. What should be the size of expansion tank for use with the overhead system?

A. The same size as for the regular two-pipe system.

6. Q. What should be the size of the main riser or risers for the overhead system?

A. The area of a main riser or risers should be equal to the valve areas of all radiators supplied. This rule is the same as used for the regular system of two-pipe heating.

7. Q. What should be the size of the branches supplying the drop risers?

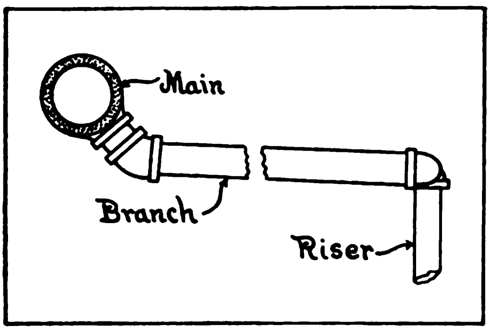


Fig. 57.—Method of Connecting Branch for Overhead System.

A. The size of branches should be the same as for the two-pipe system. As a rule each branch should have an area equal to the valves on the radiators supplied by it.

8. Q. What should be the size of the drop risers for use with the overhead system?

A. As the water is the hottest at the top of the system and cools and contracts in its descent it would seem that the riser might be reduced in size at the bottom of the system. This, however, is not good practice and on ordinary work it is best to run the drop risers full size to the bottom of the system; this size being sufficient to supply the various radiator connections fed by it. The piping sizes are very important for this system and in many cases are obtained more from practice than by calculation.

9. Q. How many valves are necessary on the radiator connections for the overhead system?

A. It is customary to use but one valve and this may be placed on the flow or on the return connection as may be desired. It is customary to make the flow connection at the top of the radiator and the return connection at the bottom of the same end of the radiator.

10. Q. **What should be the size of the radiator valves and connections?**

A. The connections for radiators of 50 square feet or less should be 1 inch. For larger radiators 1¼ inch will be sufficient. The velocity of the circulation should be figured on large work and the size of connections should be based upon the velocity of the flow.

11. Q. **How should the radiators be connected?**

A. At the top and bottom of one end. It is good practice to run the drop riser near the wall and to make swing joint connections to the radiators.

BOILER, RADIATOR, AND PIPE CONNECTIONS FOR GRAVITY SYSTEMS OF HOT WATER HEATING.

1. **Q. What trimmings or special appliances should be placed on every hot water system?**

A. An altitude gauge and a hot water thermometer.

2. **Q. Describe an altitude gauge and explain its use.**

A. An altitude gauge is a spring gauge having a dial pointed off and numbered to represent the height of the water above the

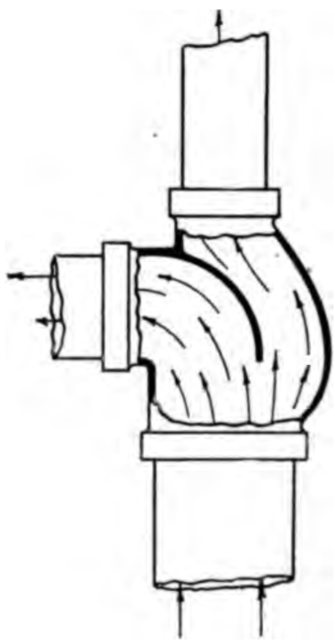


Fig. 58.—The O S Fitting.

gauge in feet. It is built on the same principle as a Bourdon steam gauge. Any increase in pressure due to height of the water spreads or opens the hollow curved tube inside of the gauge; this action is transmitted by levers to the pointer on the dial which at once swings around to register the increased height of the water. This pointer is black. An additional red pointer, which is stationary, is placed on the dial. When the system has been completely filled

with water the position of the black pointer showing the height of the water is noted, the face of the gauge removed, and the red pointer is moved with the fingers to a corresponding position. Should the water be lowered by evaporation or otherwise the fact will be shown on the altitude gauge at the boiler, the reduced pressure allowing the black pointer to fall back from its former position and additional water should then be added to the system until the black pointer returns to its former position over the red

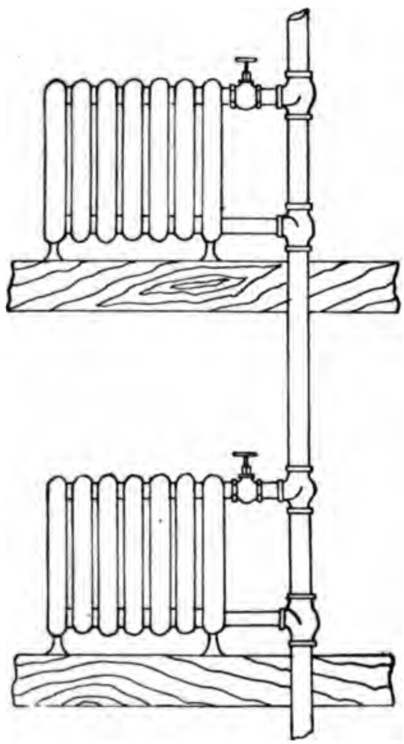


Fig. 59.—O S Fittings Used on Drop Supply Risers.

pointer. The loss of water is indicated and the system refilled to the proper height at the basement without the necessity of climbing to the top of the building to examine the water gauge on the expansion tank.

3. **Q. What is a hot water thermometer and for what purpose is it employed on a hot water heating apparatus?**

A. This thermometer is an ordinary temperature thermometer with the bulb containing the mercury or liquid encased in a thin

brass cup which is usually screwed into an opening or tapping of the boiler arranged for the purpose. Its purpose is to correctly register the temperature of the water in the boiler as a guide for the attendant in adjusting the dampers of the boiler to provide the proper degree of warmth in the building.

4. **Q. What should be the temperature of the water at the boiler on an open tank system in coldest winter weather?**

A. The best results are obtained from a system with a boiler and radiators of sufficient size to furnish the proper heat with the water at 180 degrees at the boiler; a less temperature than this is better and a higher temperature is not considered economical.

5. **Q. At what temperature should the water return to the boiler?**

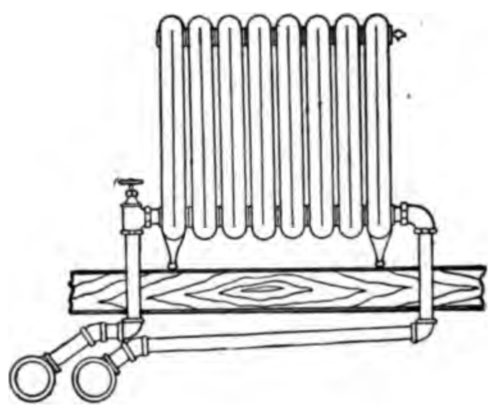


Fig. 60.—Radiator Connected at Bottom of Both Ends.

A. Generally speaking at a temperature not more than 20 degrees cooler than the flow. On a well proportioned job this difference is very much less than 20 degrees.

6. **Q. What should be the size of the flow pipes out of the boiler?**

A. The same area as the mains which they feed.

7. **Q. When a header is used to connect two boilers or two or more openings of the same boiler what should be its size?**

A. The header should have an area equal to or exceeding the area of all mains or flow pipes supplied by it.

8. **Q. What should be the size of the return header?**

A. The same area as the flow. The return header should always be connected identically with the flow header.

9. **Q. What special type of fitting is recommended for hot water work?**

A. The O. S. Distributing Tee.

10. **Q. What is this fitting and why superior for hot water work?**

A. Fig. 58 shows the character of the fitting. It is particularly serviceable for use on risers to divide the flow between the various floors and saves extra elbows and nipples in making such connections. It is also employed to good advantage on the drop risers of an overhead system. Fig. 59 shows its application.

11. **Q. Why is it called an "O. S." fitting?**

A. It is so called as O. S. are the initials of the heating engineer who designed and patented it—Oliver Slemmer of Cincinnati, Ohio.

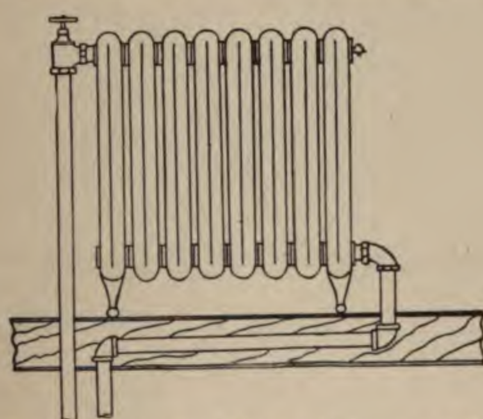


Fig. 61.—Radiator Connected at Top and Bottom of Opposite Ends.

12. **At what point of a hot water system should the water connection for filling it be made?**

A. At the bottom or lowest point in order to better force the air from the piping and radiators.

13. **Q. How is the air removed from the radiators?**

A. Through common compression air valves. These are lock and shield valves operated with a key in order that the valve may not be tampered with or inadvertently opened, thus allowing the water in the system to escape.

14. **Q. How should a hot water system be filled?**

A. Open all of the air valves and turn on the water. When the

lower or first floor radiators are partially filled close all of the air valves until the water had reached the floor above; then open the air valves on the first floor radiators one by one until the air in each radiator has escaped and it is filled with water, then proceed to the next floor above and repeat the method. Finally when all radiators are filled allow the water to run until the expansion tank is about one-quarter filled. The system is then ready for firing.

15. Q. **When radiators are located below the main piping system or on a level of the boiler how should they be supplied?**

A. By a connection taken from a riser to an upper floor at such

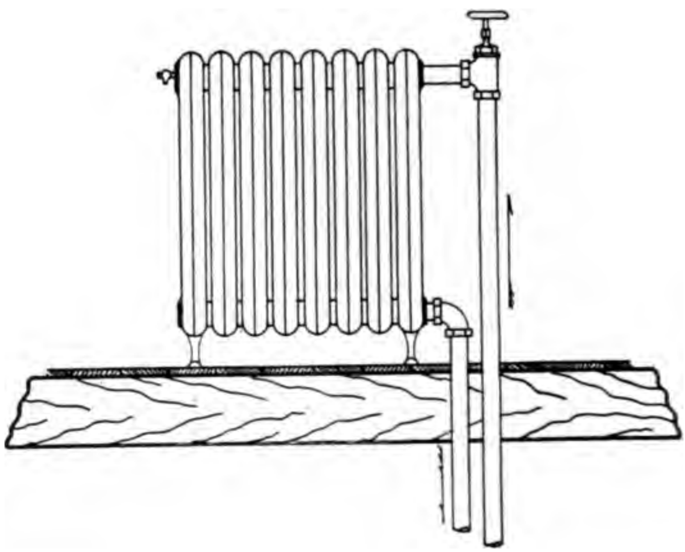


Fig. 62.—Radiator Connected Top and Bottom of Same End.

a height that a pressure from the weight or height of water in the connection will circulate the water through the radiator.

16. Q. **How are the radiators connected for hot water heating?**

A. On the ordinary system, and also on a circuit system, three methods may be used in connecting the radiators. (a) The flow may be connected at the bottom of one end and the return at the bottom of the opposite end. Fig. 60. (b) the flow may be connected at the top of one end and the return at the bottom of the opposite end. Fig. 61. (c) the flow may be connected at the top of one end and the return at the bottom of the same end. Fig. 62.

BOILER, RADIATOR, AND PIPE CONNECTIONS FOR GRAVITY SYSTEM OF HOT WATER HEATING

17. Q. What style of connection is most frequently employed?

A. The first method with flow and return at bottom of opposite ends.

18. Q. How are radiators connected for the overhead system?

A. Usually with the flow at the top and the return at the bottom of the same end and swing joints are employed on the drop riser in making the connection. Fig. 63.

19. Q. What should be the size of the radiator tappings for an ordinary system of hot water heating?

A. The lower floor tapping should be larger than that for the second or upper floors.

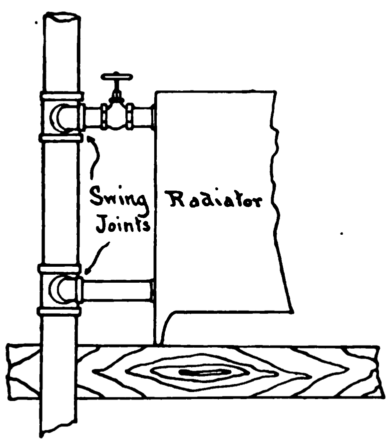


Fig. 63.—Radiator Connected for Overhead System.

20. Q. What is the reason of this?

A. There is a tendency for the hot water in circulation to pass immediately to the upper floors and for this reason the connections for upper floors must be choked by reducing their size and the connections to first floor radiators are favored by increasing their size.

The following table gives the sizes of radiator tappings that will be found best for open tank hot water work. This table varies somewhat from the standard table published by radiator manufacturers:

RADIATOR TAPPINGS FOR HOT WATER.

(Open Tank Up-Fed System)

First Floor.

Size of Radiator	*Size of Tapping*
25 square feet or less	¾ inch
25 to 50 square feet	1 inch
50 to 85 square feet	1¼ inch
85 to 125 square feet	1½ inch

Second Floor.

40 square feet or less	¾ inch
40 to 60 square feet	1 inch
60 to 100 square feet	1¼ inch
100 to 175 square feet	1½ inch

Third and Higher Floors.

50 square feet or less	¾ inch
50 to 80 square feet	1 inch
80 to 125 square feet	1¼ inch
125 square feet and larger	1½ inch

Hot Water Radiator Tappings.

(Indirect Heating.)

Size of Radiator	*Size of Tapping*
50 square feet or less	1 inch
50 to 100 square feet	1¼ inch
100 to 160 square feet	1½ inch
160 square feet and larger	2 inch

21. Q. **What pitch should be given to the mains of a hot water system?**

A. They should pitch up from the boiler from ½ to 1 inch for each 10 feet of length.

22. Q. **What pitch should be given to the branches?**

A. At least 1 inch in each 5 feet of length.

23. Q. **What should be the size of the main?**

A. The sizes of the mains are conditioned by the square feet of radiation supplied, which in turn conditions the size of the valves; therefore we may say that the area or size of a hot water main is conditioned by the valve area supplied by it. Its cross sectional area should equal or exceed the area of all valves supplied.

BOILER, RADIATOR, AND PIPE CONNECTIONS FOR GRAVITY SYSTEM OF HOT WATER HEATING

24. Q. How are the sizes of branches determined?

A. By the same method. Under ordinary conditions the following table will give the sizes of pipe required to supply a given amount of radiation. This table is compiled from standard authorities and represents the maximum amount of radiation that should be placed on a pipe of any given size.

SIZES OF MAINS AND BRANCHES.

Mains.		Branches and Risers Square Feet of Surface in Radiators.			
Size of Pipe Inches.	Square Feet of Surface In Direct Radiation.	To First Floor.	To Second Floor.	To Third Floor.	To Fourth Floor.
¾	....	....	40	45	50
1	....	50	75	80	85
1¼	135	110	120	135	150
1½	220	180	195	210	230
2	350	290	320	350	370
2½	460	400	490	525	550
3	675	620	650	690	730
3½	850	820	870	920	970
4	1,100	1,050	1,120	1,185	1,250
4½	1,350	1,325	1,400	1,485	1,560
5	1,700	....	....	....	....
6	3,600	....	....	....	....

ACCELERATED HOT WATER HEATING.

1. **Q. What is an accelerated system of hot water heating?**

A. A system in which the circulation of the water is assisted or accelerated by employing some special device which seals the system to the atmosphere and maintains a slight pressure on it. This pressure accumulates until it equals approximately ten pounds or until the water in the system has reached a temperature of 140 or 150 degrees (dependent upon the kind of appliance employed) when it is relieved automatically by the operation of the device which breaks the seal and permits all excess expansion of the water to pass to the expansion tank.

2. **Q. In what way has the accelerated system an advantage over the sealed tank or ordinary pressure system?**

A. As has already been explained, the employment of a safety valve in sealing the outlet of the expansion tank, in order to operate the system under a pressure, is a dangerous practice. Not so, however, when a special device is used. Such devices are set to work automatically and to operate when the pressure has reached the point at which they are set. Some of the devices at present in use operate with a mercury seal which holds the pressure to a given point, others employ a balanced valve, and still others make use of a spring which controls the mechanism of the valve.

3. **Q. What are the advantages of an accelerated system over the regular open tank gravity method?**

A. Greater flexibility and a greater range of temperatures. More heat units given off per square foot of radiation per hour, enabling a considerable reduction in the amount of radiation required, and owing to the increased velocity of the circulation much smaller pipe, fittings, and valves are used for the accelerated systems than would be required for the open tank systems.

4. **Q. What names are given the devices described?**

A. Generators, Heat Generators, Heat Economizers, Heat Retainers, etc.

5. **Q. What device was first employed to accelerate the circulation in a hot water system?**

A. It is probable that the Honeywell Generator was the first mercurial device to be used for this purpose and the Phelps Heat

Retainer was one of the first devices of the balanced valve type to be put on the market.

6. **Q. What is the construction of the Honeywell Generator?**

A. A sectional illustration is shown by Fig. 64. The generator is composed of two hollow castings which are joined by a wrought

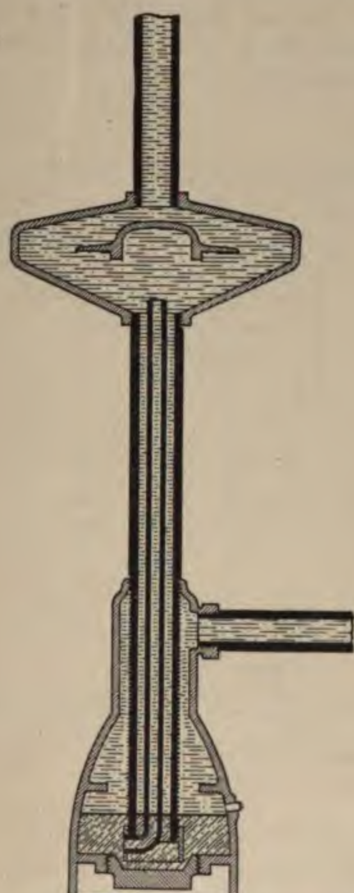


Fig. 64.—Sectional View of Honeywell Generator.

iron pipe. The upper casting is elliptical in shape and is called a separating chamber, the bottom casting is bottle shaped. This is called the mercury pot. The illustration shows the general construction of the device. A small pipe called a circulating pipe is held in position on the interior of the pipe connecting the castings.

This connecting pipe is screwed down through the neck of the bottle shaped casting to a point near the bottom of it and a shoe somewhat the shape of a reducing coupling is screwed on the pipe at the lower end. The small circulating pipe is attached to and has its inlet through the side of the shoe. A plug is screwed into the bottom of the lower casting which is then partially filled with mercury, a sufficient quantity (about 1 inch in depth in the mercury pot) being used to hold the pressure in the system until a pressure of 10 pounds has been reached.

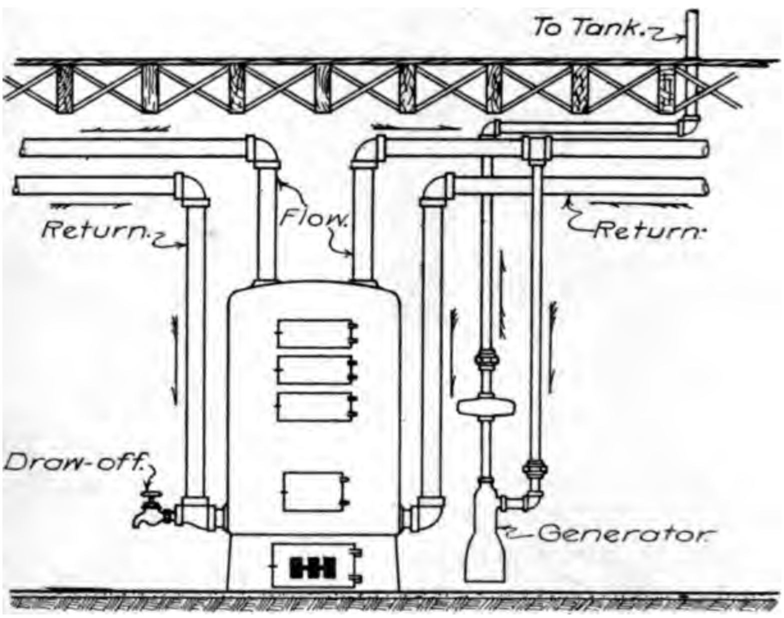


Fig. 65.—Generator Connected to System in Basement.

7. Q. What is the action of the generator in operation?

A. The expansion pipe of the system is connected into the side of the bottle shaped casting above the mercury. The pipe leading to the expansion tank is connected from separating chamber at the top of the generator, Fig. 65. The mercury in the generator is between the water in the system and the water in the expansion tank. When the water is cold the mercury lies at the bottom of the mercury pot. As the water in the system is heated it begins to expand, the expansion pressing downward upon the mercury through the side connection to the mercury pot, thus forcing it upward

in the connecting and circulating pipes. The mercury rises higher and higher in the pipes as the pressure increases until a pressure of approximately 10 pounds has been reached, when the generator is in full and complete operation. Fig. 66.

The mercury has now been forced to the top of the pipes and

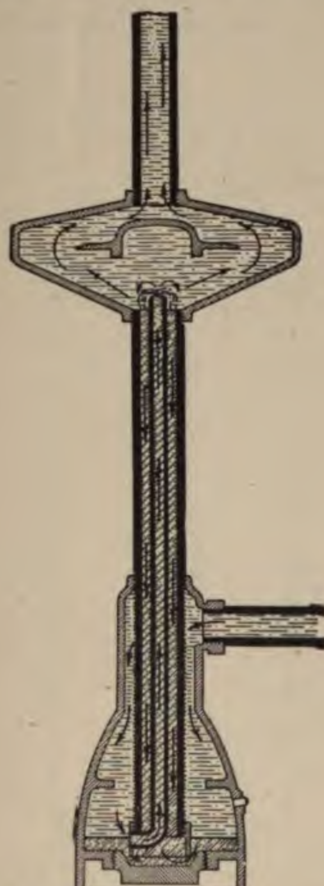


Fig. 66.—Generator in Full Operation.

begins to circulate, passing upward through the circulating pipe and downward through the larger pipe connecting the castings. The small circulating pipe extends above the larger connecting pipe and the difference in height and weight of the mercury in these pipes starts the circulation. Any water carried upward with the

mercury through the circulating pipe separates from the mercury in the upper casting or separating chamber. The weight of the mercury holds or maintains the pressure.

8. **Q. What other mercurial devices are used for accelerated heating?**

A.. The Milwaukee Tank Generator, the Pierce Heat Economizer the Klymax Heat Economizer and several others.

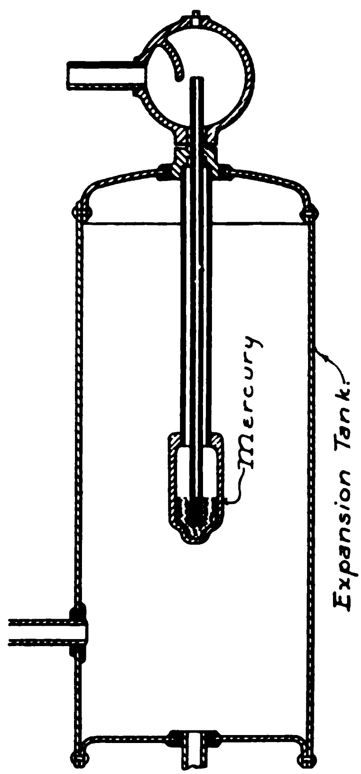


Fig. 67.—The Milwaukee Heat Generator.

9. Q. How do these appliances operate?

A. The Pierce Heat Economizer is in many respects quite similar to the Honeywell Generator in construction and operation. The Milwaukee Heat Generator is placed in the upper part of the expansion tank with the separating chamber above the tank. Its appearance is shown by Fig. 67. The Klymax Heat Economizer

is a mercury device placed on the expansion line below the tank or between it and the heating system.

10. Q. **Describe the Phelps Heat Retainer.**

A. The Phelps Heat Retainer operates by the opening and closing of a double acting valve. The valve opening to the tank and atmosphere is weighted and operates only when the water in the system has reached a temperature of 250 degrees or about 16½ pounds pressure.

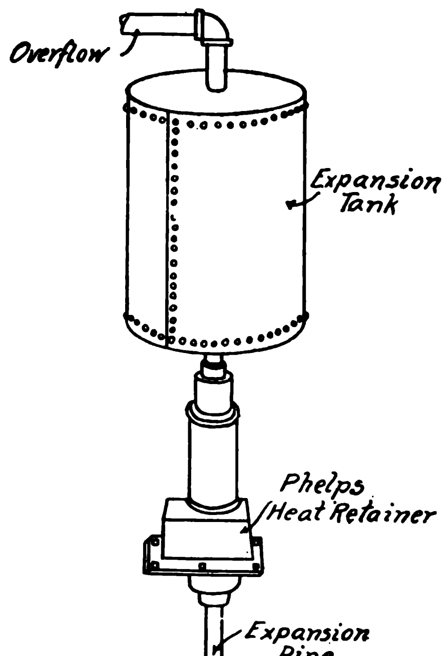


Fig. 68.—The Phelps Heat Retainer.

The valve is encased in a cast iron boxing and the device is connected to the heating system immediately below the expansion tank. When the pressure increases above 16½ pounds the valve leading to the expansion tank operates, allowing the expansion to reach the tank. When the pressure goes below 16½ pounds the weight closes this valve and the shrinkage of the water opens the retainer valve, allowing it to flow back into the system. Fig. 68 shows the appearance of the device and the method of connecting it to the system.

11. **Q. What other generator operates on the principle of a double valve?**

A. The Belknap Generator.

12. **Q. Describe the installation and operation of the Belknap Generator.**

A. Fig. 69 shows the interior of the device and the controlling

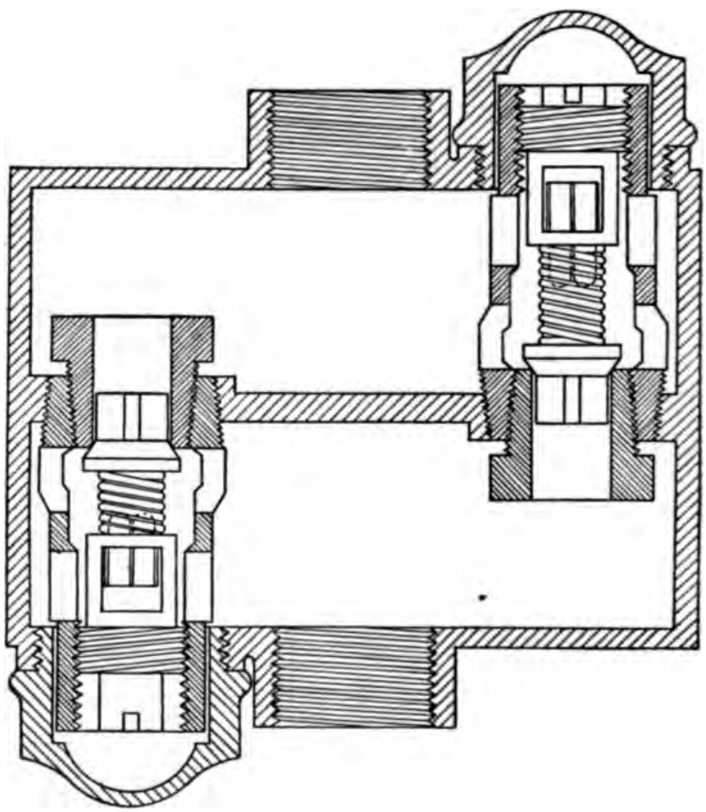


Fig. 69.—The Belknap Generator.

valves A and B. It is placed on the expansion line between the tank and heating system.

As the water expands a pressure is created against the valve B. The spring of valve A is adjusted to withstand a pressure of 10 pounds. When the pressure rises above 10 pounds valve A opens and allows the excess expansion of the water to pass the tank. As the pressure lowers a vacuum is created in the system which, aided by the static

pressure of the water above the valve, causes it to open and allows the water to return again to the system.

13. **Q. What other devices are used for placing a system under a slight pressure?**

A. There are several other devices used for the purpose, some operating with valves and some without valves. The B Heat

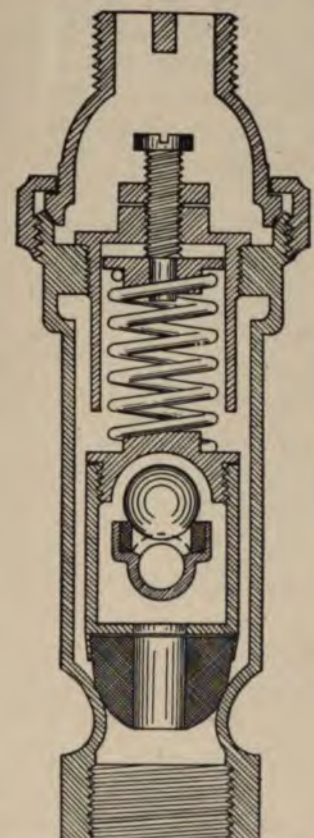


Fig. 70.—The B Heat Intensifier.

Intensifier is one of the spring valve variety. An interior of this is shown by the illustration Fig. 70, which displays the mechanism of the double acting valve. Like other devices of the kind it is placed on the expansion line under the tank or in the basement near the boiler.

14. **Q. What is known as the Honeywell System of accelerated heating?**

A. Mr. M. C. Honeywell in the development of the Honeywell Generator devised, and experimented with, certain styles of pipe connections designed to equalize the flow of the water through the system, and this, together with the generator, has come to be known as the "Honeywell System."

15. Q. What size of piping is employed for a Honeywell system as compared with an open tank system?

A. Pipe sizes are very much smaller for use with an accelerated system due to the fact that smaller valves and radiator connections are employed. The small sizes of piping used are based not alone on valve areas, but on the rate of heat transmission from radiators located at different heights and the velocity of the flow to the radiators thus located.

16. Q. What sizes of valves are required for the radiators when attached to an accelerated system?

A. For radiators located on first floor.

25 square feet or less	½-inch valve
25 to 50 square feet	¾-inch valve
50 to 125 square feet	1 -inch valve

For radiators located on second floor:

30 square feet or less	½-inch valve
30 to 125 square feet	¾-inch valve
125 square feet or more	1 -inch valve

For radiators located on third (or upper) floor:

40 square feet or less	½-inch valve
Over 40 square feet	¾-inch valve

17. What rules are given for the successful installation of accelerated piping?

A. *Rule 1.* The main should always end at a first floor radiator. If this radiator is 40 square feet or less in size a ¾-inch valve may be used. For radiators exceeding 40 square feet a 1-inch valve should be used, and the size of the main at its termination should be two pipe sizes larger than the connection to the radiator.

Rule 2. A branch should never be connected from the top of a main. There are three styles or types of radiator or branch connections from the mains as employed on Honeywell or accelerated systems. These are known as the "A," "B" and "D" connections. Fig. 71.

The "A" connection is employed in taking a branch from the main to supply a first floor radiator or a branch to a first floor

radiator which also supplies a riser to an upper floor. This connection is employed only at points where no reduction in the size of the main is made.

The "B" connection is employed for the same purpose at points where a reduction is made in the size of the main in order to relieve it of air which would otherwise collect at this point. The eliminating of air pockets is an important step towards the installation of a successfully working system.

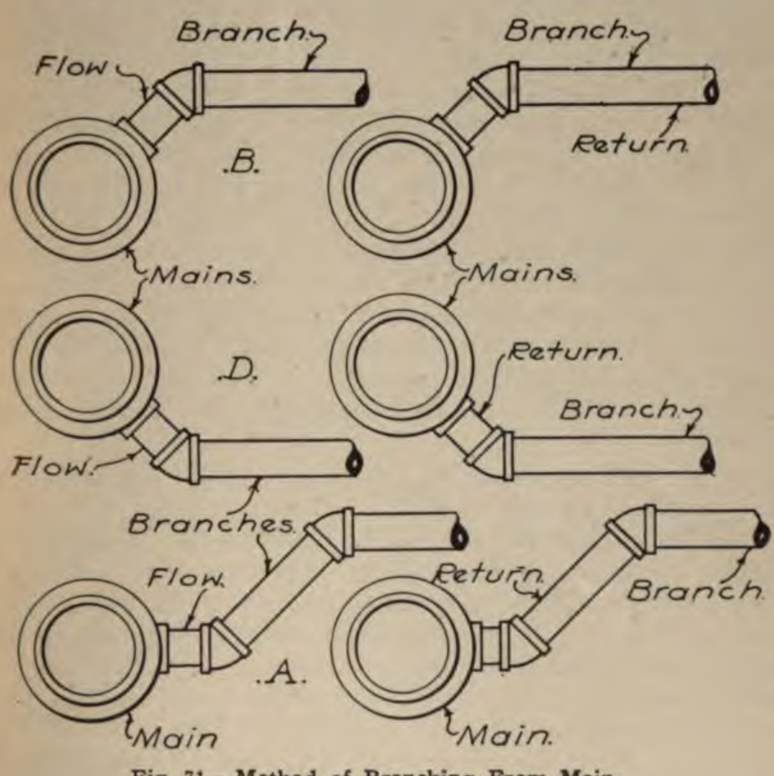


Fig. 71.—Method of Branching From Main.

The "D" connection is employed in taking branches from a main to supply risers to upper floors and may also be used to connect a branch to a first floor radiator located very near the boiler as its use in this manner prevents the short-circuiting of the circulation and materially assists in balancing the job.

Rule 3. As the pipe sizes employed are small, any foreign substance in the pipe will interfere with the circulation and all lengths

of pipe before placing in position should be stood on end and hammered to remove scale or the possible clogging of dirt, and all pipe should be reamed to remove the burr made by the cutting tool.

Rule 4. When a radiator or a group of radiators are connected from the main at a point very near to the boiler the return circulation is quicker and hotter than that from distant radiators, and it is well to make a separate return connection from them, connecting the return into the side of the main return at the bottom of the boiler. This connection will help to equalize the circulation.

18. Q. What sizes of mains are employed for an accelerated system?

A. The sizes of mains to be used for an accelerated system are determined in the same manner as for an open system, namely, by the valve area of all radiators supplied. The main should never be reduced so that its area is less than the area of all valves beyond the point of reduction.

19. Q. Are branches and risers for an accelerated system run or installed the same as for a gravity system?

A. There is no difference whatever in the method of running branches and risers or connections to upper floor radiators other than has been stated in the rules given. The pitch of the main and the pitch of branches should be the same as for an open tank system.

20. Q. Where should the altitude gauge be located on an accelerated system and why?

A. The altitude gauge should be placed on the expansion pipe leading to the tank *above* the generator or device employed. It is placed thus to indicate the true height or weight of water in the system. Should it be placed on the boiler as with an open system any pressure registered on the system would be indicated on the gauge, the spring of the gauge opening so that the pointer would not register the height of the water correctly.

21. Q. What size of expansion tank should be employed for use with an accelerated system?

A. The same size as would be employed for an open tank system. There is no difference in the expansion of the body of water in the system, and the tank size should be sufficient to accommodate the increase in bulk through 200 degrees range of temperature.

22. Q. What amount of radiation is required for accelerated heating as compared with the open tank system?

A. A reduction of 10 to 15 per cent. in the amount of radiation

required for an open system may safely be made for an accelerated system for the reason that range of temperatures is greater with the accelerated system. The limit of temperature with an open tank system is 212 degrees and this temperature is seldom reached without the water boiling. The limit of temperature of an accelerated system, as has already been explained, is 240 or 250 degrees, depending upon the apparatus used, and hence less radiation is required.

23. Q. **When it is necessary to place the expansion tank of an accelerated system in a cold room or attic, requiring that it be circulated, what method of installation should be followed?**

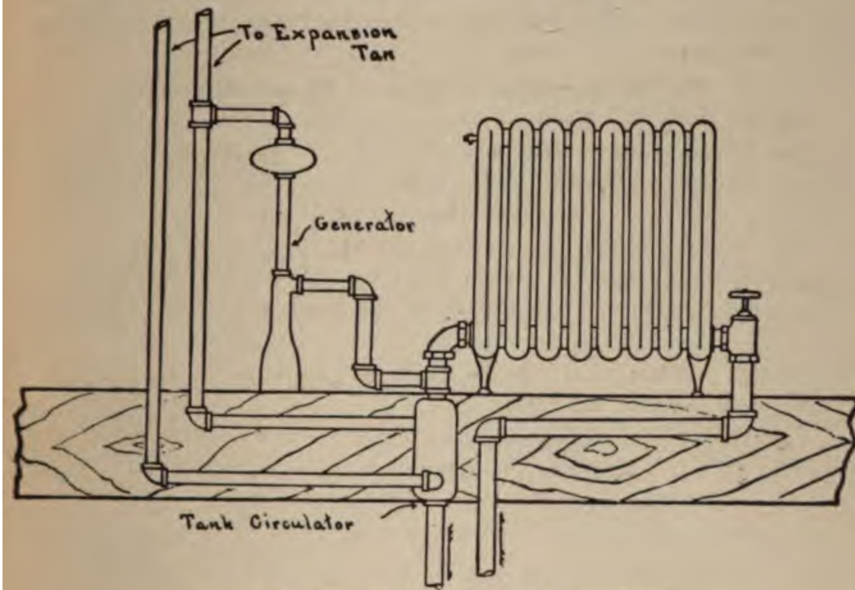


Fig. 72.—The Honeywell Tank Circulator.

A. The tank cannot be circulated in the ordinary manner without destroying the pressure caused by the accelerator. It is therefore necessary to use a small heater called a tank circulator. This is a hollow casting having an inner and outer compartment. It is connected to the system in such a manner that the hot water in circulation passing through the inner compartment warms the water in the outer compartment which is connected directly to the tank. Fig. 72 shows the Honeywell tank circulator and a method of connecting it to the heating system.

24. Q. What method other than those described is used to force or accelerate the circulation through a hot water system?

A. Pumps are sometimes employed to force the circulation, particularly on large jobs where the water is heated by exhaust steam.

25. Q. What type of pumps is most frequently used?

A. Pumps of the centrifugal type. These are driven by steam or by an electric motor.

26. Q. What general method of installation is used?

A. It is common on large work to place the pump in a position to receive the returning circulation and force it through a live or exhaust steam heater, and thence through the heating system. Some systems employ two heaters, one for exhaust, and the other for live steam.

27. Q. What are the advantages of using two heaters?

A. The coldest water of the return circulation is first forced through the exhaust heater, which tempers it. It then flows through the live steam heater, which heats it to the maximum temperature desired.

28. Q. What methods of piping are especially adapted for use with this system?

A. The overhead system and the circuit, or one-main, system.

EXPANSION TANK CONNECTIONS.

1. Q. What general methods are employed in connecting the expansion tank to a hot water system?

A. Three methods may be used: (a) Connecting the tank to the system without circulating the water to or in it; (b) connecting the tank to the system in such a manner that there is a circulation of hot water to the bottom of the tank; (c) connecting the tank in such a manner that the water in it will be circulated or heated.

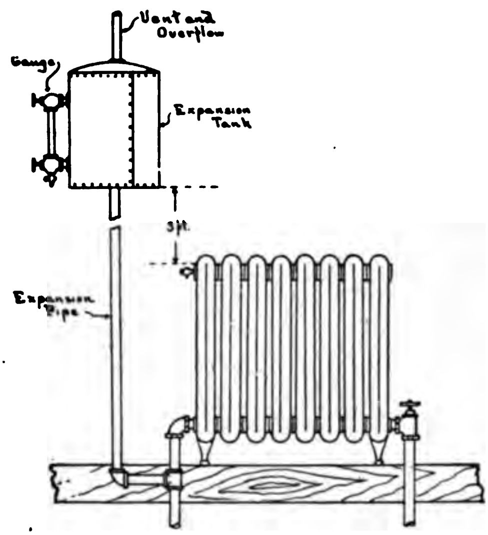


Fig. 73.—Expansion Tank Connection—No Circulation.

2. Q. Describe each of these methods.

A. (a) This method is illustrated by Fig. 73. The expansion line may be connected from the return of one of the high radiators on the system as shown, or it may be run to the basement and there connect with the return at the boiler.

(b) The method of connecting the tank to circulate the water to it is shown by Fig. 74. The flow pipe may be connected from any convenient flow riser and the return pipe to any convenient return riser at the top of the system. These are joined together immediately under the tank in the manner shown and the connec-

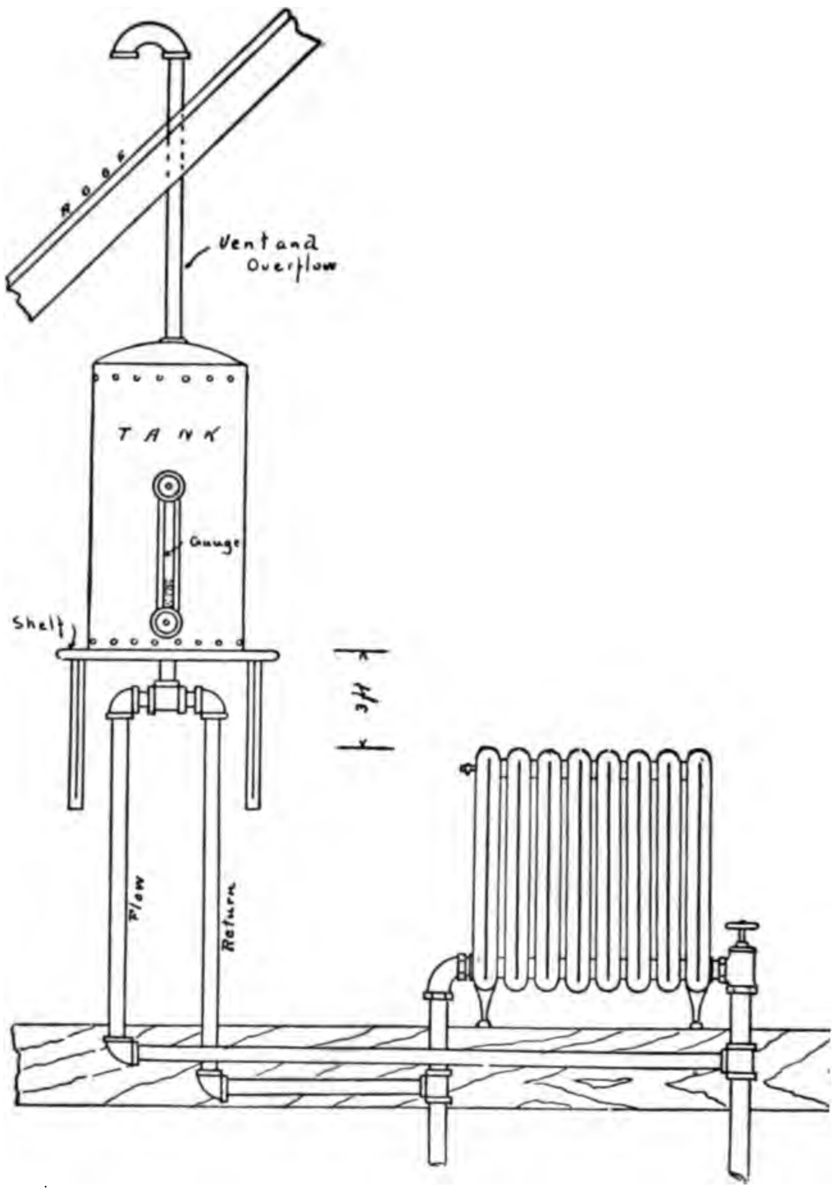


Fig. 74.—Expansion Tank Connection—Circulation to Tank.

tion to the tank from the top of the loop acts as an air vent, the water passing upward to the tank through the flow and downward through the return as the circulation is established in the system.

(c) The flow connection to the tank should be connected into the side opening of the tank and may be run from any convenient flow riser. The return pipe in this instance is taken from the bottom of the tank and connects with a return riser. Fig. 75 illustrates the

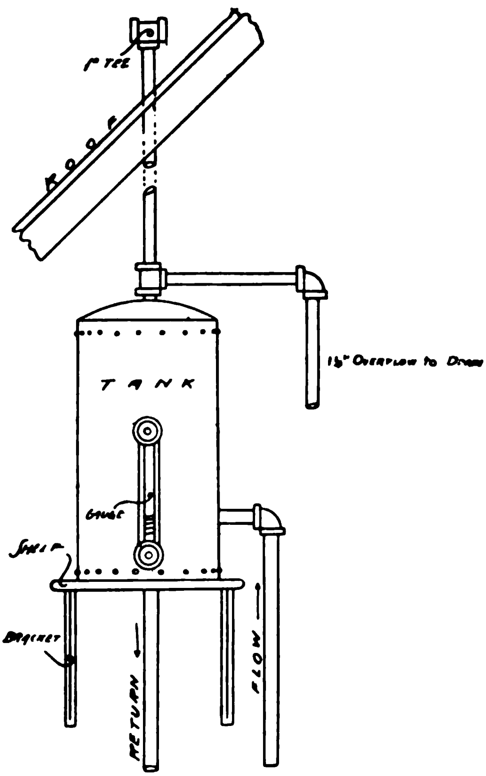


Fig. 75.—Expansion Tank Connection—Circulation in Tank.

method. The tank when connected in this manner should be kept at least one-third full of water, and owing to this fact a larger size of tank than would ordinarily be employed is necessary to give capacity for the natural expansion of the water when heated.

3. **Q. How should the vent pipe from the tank be connected?**

A. It may be connected as shown on either one of the illustra-

tions already given. It should always be connected from the top of the tank and should be run through the roof or through the side of the building near the tank. If connection is made through the side of the building the horizontal pipe should pitch slightly towards the outside in order that no water may lodge in the pipe and freeze.

4. Q. How should the overflow from the expansion tank be connected?

A. The vent pipe above referred to may also serve as the overflow pipe or a tee may be placed on the vent pipe immediately above the tank, and the side outlet of the tee used to connect the overflow pipe, or the side tapping of the tank may be used to connect the overflow.

5. Q. Is the running or connecting of the overflow into an open plumbing fixture, such as closet tank, advisable or good practice?

A. No, it is not. If the overflow is connected separately from the vent pipe it should be carried to basement of the building and there be connected into some convenient drain or waste pipe.

6. Q. Is the use of valves on expansion tank connections necessary or advisable?

A. Valves should never be placed on expansion tank connections. These pipes should be kept free and open in order to prevent the possibility of the closing of the system to the atmosphere and thus inadvertently place the same under pressure.

7. Q. How can the capacity of a round expansion tank be determined?

A. Multiply the square of the radius of the tank in inches by 3.1416, then multiply this amount by the length of the tank in inches. Divide this result by 231, which represents the number of cubic inches in a gallon, and the result will be the capacity of the tank in gallons.

8. Q. What simple rule may be used for determining the size of the expansion tank required for a hot water system?

A. For an installation requiring 500 square feet or less allow one gallon of tank capacity for each 30 square feet of radiation.

For 500 to 1,000 square feet of radiation allow one gallon of tank capacity for each 40 square feet.

For 1,000 to 3,000 square feet of radiation allow one gallon of tank capacity for each 50 square feet.

For 3,000 to 5,000 square feet of radiation allow one gallon of tank capacity for each 60 square feet.

This rule, while approximate, is sufficiently accurate for all ordinary work.

Or the following rule may be used:

When there is less than 1,000 square feet of radiation on a job multiply the amount of radiating surface by .03 to determine the size of the tank.

When there is between 1,000 and 2,000 square feet of radiation use the multiplier .025.

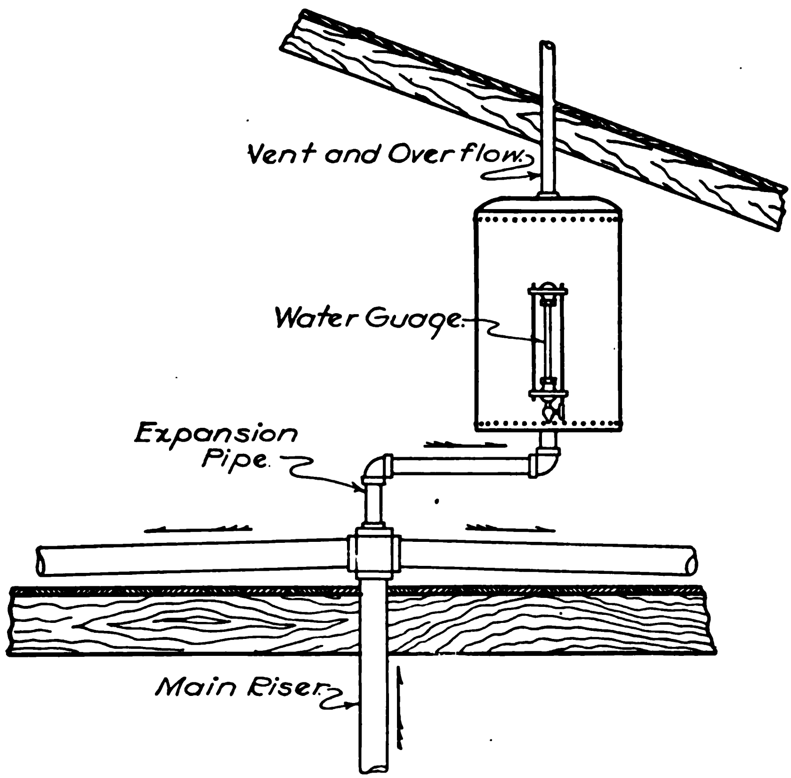


Fig. 76.—Expansion Tank Connection—Vertical for Overhead System.

For jobs requiring more than 2,000 square feet of surface multiply by .02.

This is a simple rule easily applied.

9. Q. Where should the expansion tank be located?

A. In a room that is warm in order to prevent freezing. If it is necessary to place the tank in a cold room or in an exposed position in the attic it should always be circulated in order that there

will be no possibility of its freezing in exceptionally cold weather.

10. **Q. How should the expansion tank be connected to an overhead system of hot water heating?**

A. Fig. 76 shows a method of connecting the tank vertically. This connection may be used on any small job of overhead heating. When connecting the expansion tank to a larger system of hot water heating or one requiring an expansion tank of exceptionally large size it is well to use the tank horizontally and to suspend

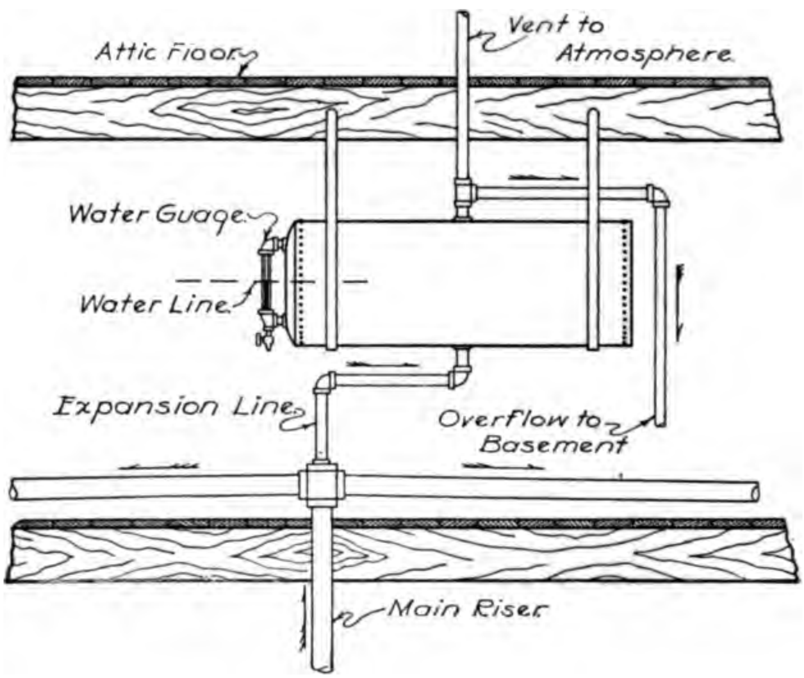


Fig. 77.—Expansion Tank Connection—Horizontal for Overhead System.

the same from the roof joints by iron straps, connecting the expansion pipe to the under side of the tank and the vent pipe from the top side of the tank. The overflow may be connected from the top or from the centre of one end of the tank as shown by Fig. 77. If the water gauge is used on a large tank suspended horizontally it should be placed at the end of the tank as shown.

11. **Q. In general what should be the size of the overflow pipe from an expansion tank?**

A. It should be the same size as the expansion pipe in order

that there will be no choking of the overflow and the consequent filling up and running over through the vent pipe.

12. Q. **At what point on a circuit or single main system should the expansion tank be connected?**

A. From the high point of the main, whether this is immediately over the boiler or at any other point on the system.

13. Q. **When an accelerated system is used what should be the position of the expansion tank, and how should it be connected?**

A. It should be located above the highest radiator as for an open system and connected so that the accelerating device used will be between the tank and the heating system.

DOMESTIC HOT WATER HEATING.

1. Q. How many methods can be used to heat a supply of water for domestic use?

A. There are two general methods. First, by heating the water directly as with a water-back in a range, a coil or auxiliary heater placed in the fire pot of a furnace or boiler, or the use of a small tank or gas heater; and second (when steam is available) by placing a steam coil within a tank and heating the water by the condensation of the steam supplied to the coil.

2. Q. What kind of tanks are employed for the storage of the water when heated?

A. The tank may be an ordinary kitchen or range boiler, or if required a special tank of larger capacity, called a storage tank, may be used. The former tank and method of connecting from the water back of the range is so familiar as to require no explanation. The tank should ordinarily be placed above the source of the heat.

A storage tank is a tank of larger size and greater capacity than a range boiler and the tappings of it are so arranged that it may be used in a vertical or in a horizontal position. When used vertically it is supported on an iron stand or legs. When used horizontally it may be hung from ceiling or floor joists with iron straps or rest upon brick, stone or cement piers.

3. Q. When a water back or water front is used in a range for heating water how is its capacity figured?

A. Water backs are commonly rated on the basis of 2 or 2½ square inches of heating surface (the face of the water back only) for each gallon capacity of the kitchen or range boiler. The capacity of a water back is largely increased at times when the range is operated to full capacity for baking, etc.

4. Q. When a coil or auxiliary heater is installed in the fire pot of a boiler how is its capacity determined?

A. Each square foot of surface of a pipe coil installed in this manner will warm from 25 to 30 gallons of water per hour, from 55 to 60 degrees (the usual temperature of the return circulation) to 130 or 140 degrees for domestic use, when the coil is placed in direct contact with the fire.

5. Q. How are tank heaters rated when they are used for warming water for domestic use?

A. The average rating of a tank heater is 250 gallons per hour for each square foot of grate surface. Tank heater ratings are usually excessive, and the fact that a large amount of the heated water is carried in storage, being heated at night or during periods of the day when but little hot water is used, is considered in rating the heater. Ordinarily 50 gallons warmed through 100 degrees would be considered a fair rating for constant service at full capacity.

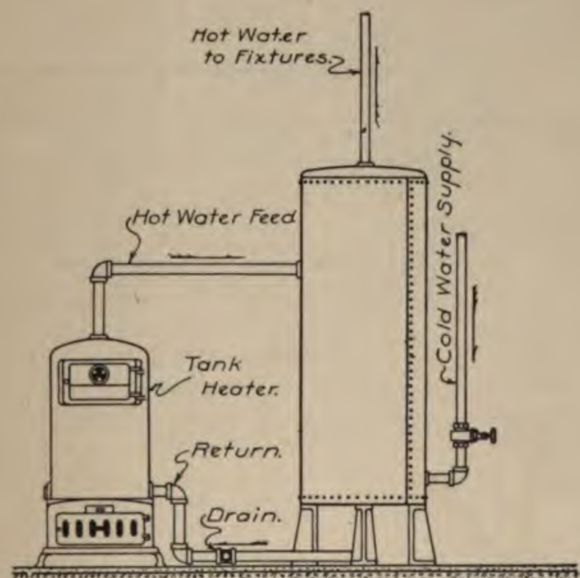


Fig. 78.—Domestic Hot Water Supply—Vertical Boiler.

6. Q. When a storage tank is installed in a vertical position how are the pipe connections made from the boiler to the tank?

A. Fig. 78 illustrates the usual method employed. The tank is placed on a stand or pedestal at such a height that the bottom of it is above the return connection of the tank heater. The flow from the heater is connected into the side of the tank about one-third distant from the bottom. The cold water supply is connected to the return pipe, which is at the bottom of the tank, and the hot water supply to the various fixtures is taken from the top of the tank.

7. **Q. When the tank is placed in a horizontal position how should it be connected to the heater?**

A. As shown by Fig. 79. The hot storage water occupies the upper part of the tank and the cooler water in circulation the lower part of the tank. The illustration shows the method of making the various pipe connections.

8. **Q. When a steam coil is placed within a storage tank what should be its position?**

A. The coil should be fastened vertically in order that the steam will flow in at the top of the coil and the water of condensation will flow out of the bottom. Fig. 80.

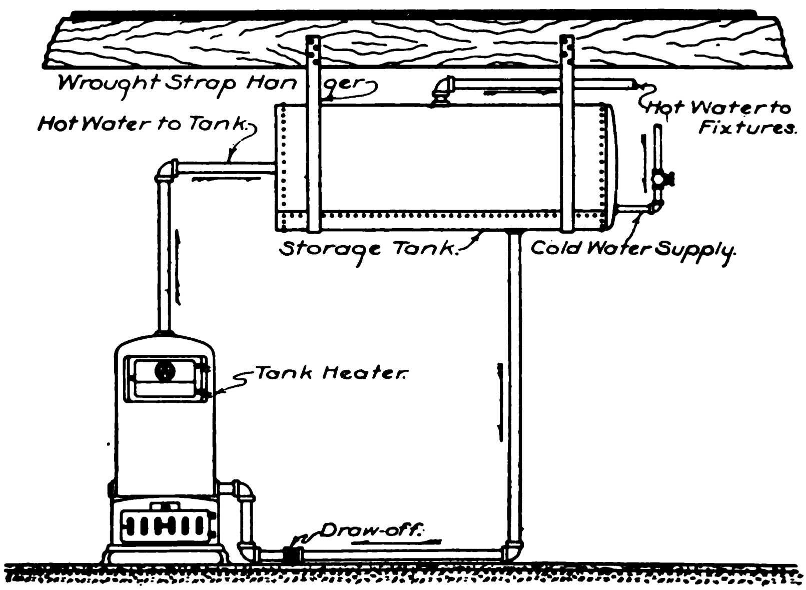


Fig. 79.—Domestic Hot Water Supply—Horizontal Boiler.

9. **Q. What size of the coil should be used in a tank?**

A. One square foot of heating surface for each 15 gallons of tank capacity.

10. **Q. Is this an economical method of heating water?**

A. It is not, unless a supply of exhaust steam (which would otherwise be wasted) is available for the purpose. Submerged coils condense an immense quantity of steam in heating water.

11. **Q. Of what material should the coil be made for warming water for domestic use?**

A. Copper, brass or galvanized iron. A galvanized coil is less effective than a brass or copper coil for this purpose.

12. Q. **What provision can be made for relieving excess pressure due to the height of a building or overheated water?**

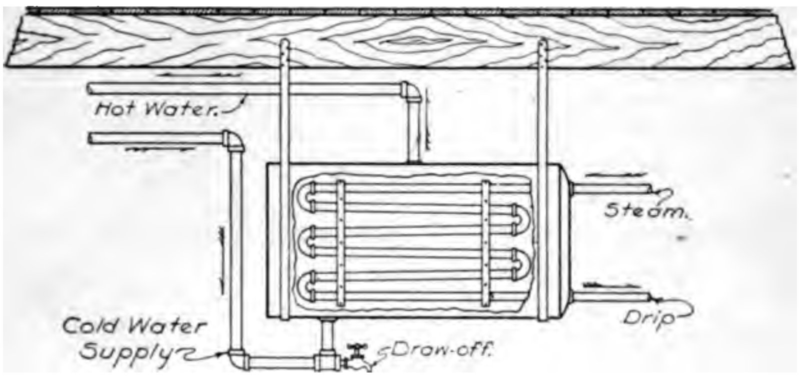


Fig. 80.—Domestic Hot Water Supply—Steam Coil in Boiler.

A. A pressure relief or safety valve may be used. This should be set to operate at five pounds above the normal pressure of the heated water (which may be 150 or 160 degrees) or at five pounds above the static pressure due to the height of the water in the system.

VALVES AND AIR VALVES.

1. Q. **What types of valves are employed on the various systems or apparatus installed for heating purposes?**

A. Globe, angle, gate and check valves in the regular or some special form.

2. Q. **What is a globe valve, and for what purpose is it employed?**

A. The common type of globe valve is illustrated by the sketch,

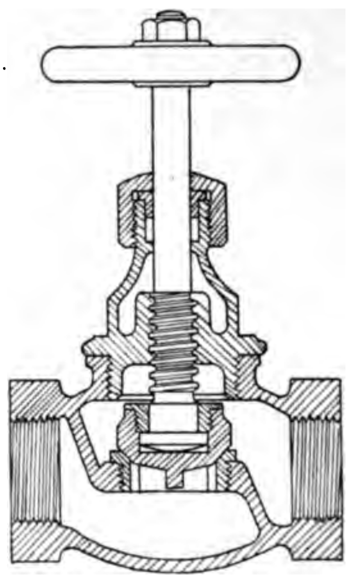


Fig. 81.—Globe Valve.

Fig. 81, which shows a sectional view of its construction. A bridge supporting the seat is cast in the body of the valve. A disc engaging with this seat is adjusted to the bottom of the valve stem which screws up or down to raise or lower the disc to open or close the valve. The stem passes through the bonnet of the valve and a wheel is provided at the top for operating it with the hand. Globe valves, owing to the restricted area of the opening through the seat, are used principally on steam work.

3. **Q. How should a globe or angle valve be placed on a line of piping?**

A. In such a position that the flow will enter the valve under the seat and against the under side of the disc.

4. **Q. How should a globe valve be placed on a horizontal pipe?**

A. When it is necessary to use a valve of this character on a horizontal pipe it should be placed with the stem in a horizontal position or pitching slightly downward; otherwise, owing to the interior construction of the valve, it will be impossible to obtain perfect drainage through the pipe. Fig. 82 illustrates this feature.

5. **Q. What type of valve may be used in any position on a line of piping and yet allow of perfect drainage?**

A. A gate valve. This type of valve, owing to its construction, offers no obstruction to drainage. The valve is opened and closed by raising or lowering a wedge shaped gate and when open admits of a full sized free opening through the valve. Fig. 83 shows this construction.

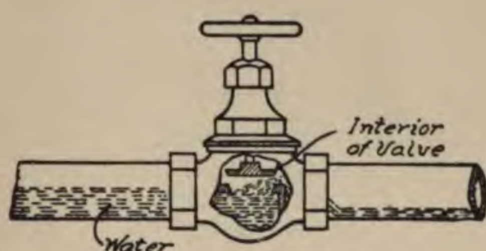


Fig. 82.—Globe Valve on Horizontal Pipe—Imperfect Drainage.

6. **Q. What is an angle valve?**

A. An angle valve is used in the position of a 90 degree elbow at a point where a change of direction is made in the flow of steam or water.

The name is usually given to the common type of angle valve as illustrated by Fig. 84, although a large share of the radiator valves used are in reality valves of the angle type.

7. **Q. What is a check valve and for what purpose is it employed?**

A. Fig. 85 illustrates several types of check valves. When it is necessary that the supply of steam or water should flow always

in one direction a check valve is placed on the pipe. The construction of the valve is such that it allows the steam or water to flow in one direction only and prevents any reverse circulation of the same.

8. Q. When extra large valves are required how are they usually constructed?

A. With a yoke over the bonnet of the valve to strengthen it and to provide a suitable guide and bracing for the large stem. Globe, angle and gate valves of large size have this construction. Fig. 86 illustrates a gate valve with yoke.

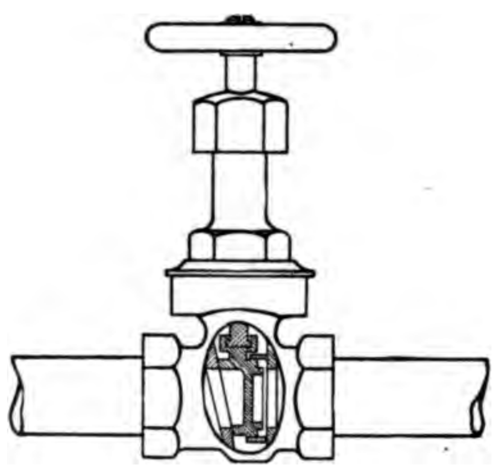


Fig. 83.—Gate Valve.

9. Q. What is the common form of a steam radiator valve?

A. The ordinary type of valve employed in making connection to a steam radiator is an angle valve having a wood wheel and a union connection for attaching to the radiator. Fig. 87 shows an outline of the standard type of valve. The usual steam radiator valve has a Jenkins or composition disc.

10. Q. What is a Jenkins disc?

A. A ring of a composition substance which is attached to the under side of the brass disc and which, when screwed against the valve seat, is intended to make an absolutely tight joint.

11. Q. What is a ground seat or Frink seat valve?

A. A valve having the edge of seat and disc ground to a taper of the same degree in order to close tightly when the stem is screwed

lown and the disc engages with the seat. Some valves of this character have a soft metal disc.

12. Q. **What objection is there to the use of a ground or soft metal seat valve on steam piping?**

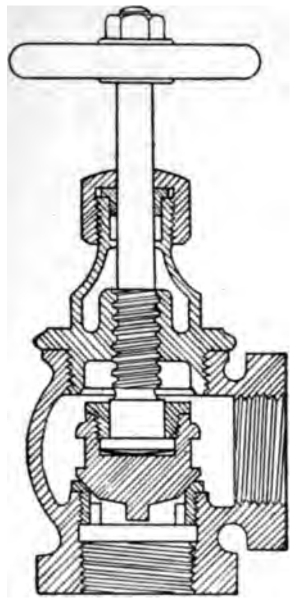


Fig. 84.—Angle Valve.

A. For the reason that they are liable to leak and the slightest leak of steam through a valve when it is turned off will cause no end of trouble and annoyance.

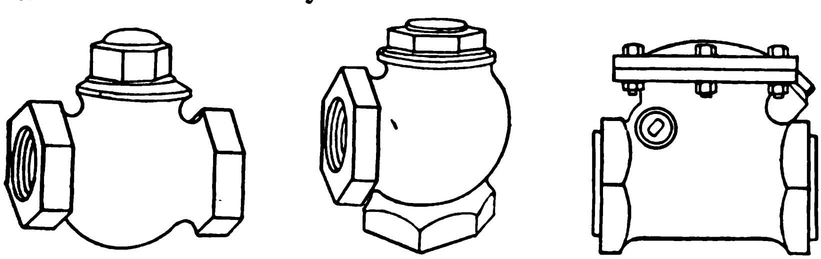


Fig. 85.—Check Valves.

13. Q. **What type of valve is used for connecting a hot water radiator?**

A. The common form is illustrated by Fig. 88. The angle type of valve is commonly employed. The body of the valve is

cylindrical and a close fitting sleeve is placed on the inside of the body. This sleeve is attached to the stem which turns it, and one side being cut away so that when the sleeve is turned with this opening facing the radiator the valve is open or there is an open passage through it.

14. Q. **What special type of radiator valve is frequently used for steam?**

A. Valves of the so-called packless type. Packless valves are

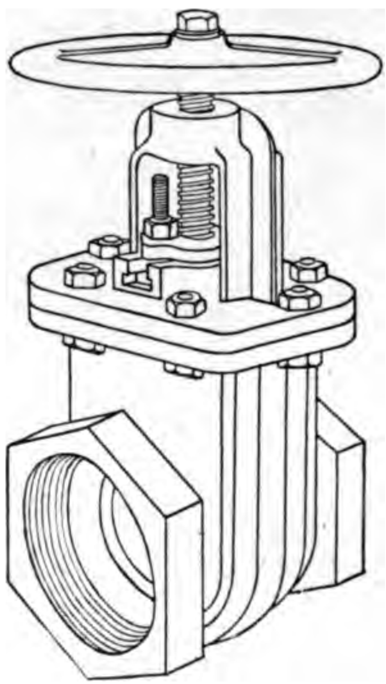


Fig. 86.—Gate Valve With Yoke.

modern and a comparatively recent improvement in method of construction.

15. Q. **What is the construction of a packless valve?**

A. A packless radiator valve is a valve specially constructed so that the hexagon nut at the top of the bonnet does not require any packing around the stem of the valve to make it tight. Packless valves are made for both steam and hot water. Fig. 89 is a sectional view of a packless hot water radiator valve.

16. Q. What special forms of radiator valves are made for use on steam radiators?

A. Right and left hand corner and straight-way valves, with and without off-set.

17. Q. How are these valves used?

A. Principally when radiator connections are made above the floor. The corner off-set valves, right or left hand, are made for connecting a radiator directly with a riser above the floor with a swing joint at the riser. The off-set feature of the valve allows of

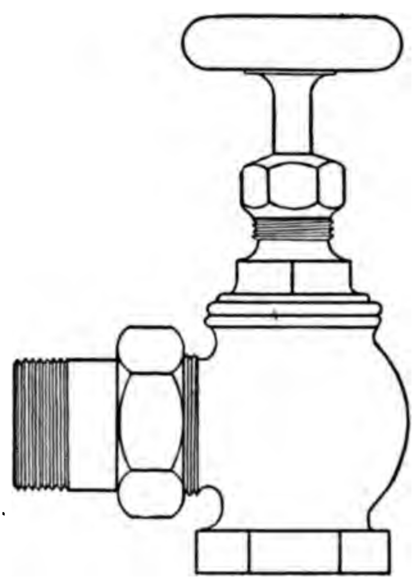


Fig. 87.—Steam Radiator Valve.

free drainage from the radiator to the riser. When a radiator is connected directly from a riser with a straight connection the straight type of off-set valve may be employed as shown on one of the radiators illustrating one-pipe connections. Fig. 36.

18. Q. What special types of hot water radiator valves are to be had?

A. Several special types of hot water radiator valves are manufactured; these are used principally in making a flow and return connection to a radiator when both connections are made at or through a single opening at one end of the radiator. The Honeywell Unique radiator valve, Fig. 90, is an illustration of a valve of

this type. The bonnet of the valve is cylindrical in shape and both flow and return pipes are joined to it by union connections quite similar in shape to a regular hot water union elbow. The valve stem engages with a double gate in the form of baffles on the interior of the body of the valve, which are set in such a position that when the valve is open to the radiator there is a passageway through one side of the valve into the radiator. The return circulation from the radiator is divided and separated from the flow by a projecting web in the spud of the valve which extends into the

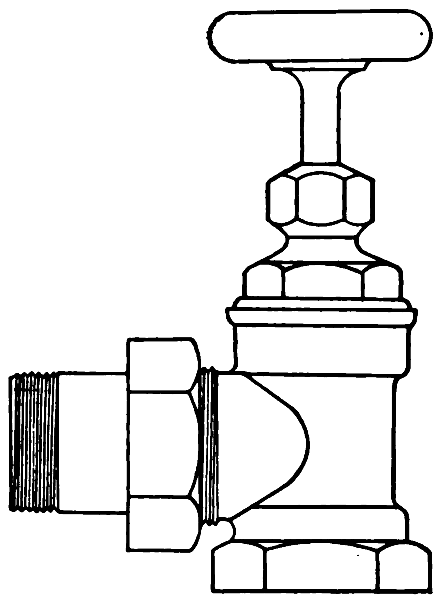


Fig. 88.—Common Hot Water Radiator Valve.

radiator through one loop or section or sufficiently far to prevent an eddy forming at the inlet and outlet of the valve, due to the flow and return moving in opposite directions. The return circulation entering the bonnet of the valve is directed towards the return connection by one of the gates or baffles inside the valve. By turning the wheel of the valve to close it, the gates are moved to such a position that both flow and return passages into the radiator are closed and the water will then circulate freely from the flow riser through the valve to the return riser without entering the radiator. A very small turn of the wheel (1-6) closes or opens the

valve by changing the position of the gates. Fig. 91 is a plan of the valve showing the position of the gates when the valve is open, and Fig. 92 shows the position of the gates when the valve is closed.

Another type of special hot water valve is shown by the illustration, Fig. 93. A fin or baffle divides the body of the valve in the manner shown on the illustration, the flow passing along the top of this baffle and the return from the radiator entering underneath it through special openings at the end of the spud provided for this purpose, the illustration clearly showing the circulation through the valve.

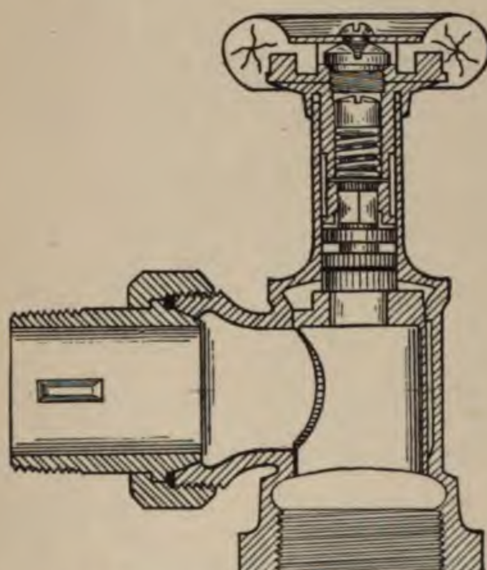


Fig. 89.—Packless Hot Water Radiator Valve.

Other special types of valves are employed for hot water; those illustrated, however, will give a very good idea of the character of the single end valve or valves for connecting both flow and return to a single opening of the radiator.

19. **Q. For what purpose are air valves employed?**

A. Air valves are used on coils, radiators and piping for the purpose of providing an outlet for the air when it is forced from a heating system by a pressure greater than that of the atmosphere.

20. **Q. How many types of air valves are manufactured?**

A. Two general types. Positive and automatic.

21. Q. What is a positive air valve?

A. The regular type of positive air valve for steam is illustrated by Fig. 94. This valve is provided with a wood wheel or handle for operating it, and must always be opened and closed by hand.

22. Q. What type of air valve is employed on hot water radiators?

A. A positive air valve frequently called a compression valve, having a lock and shield and which is operated with a key, is regularly used on a hot water system when air valves are required. Fig. 95 shows the ordinary shape of this valve.

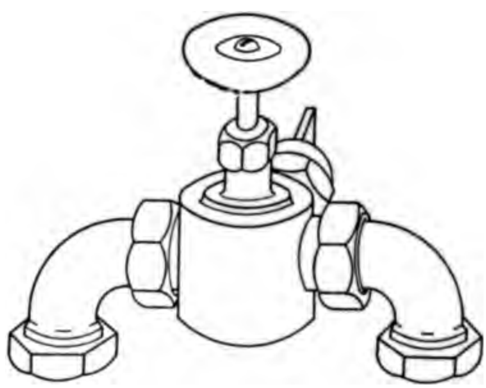


Fig. 90.—Honeywell Unique Radiator Valve.

23. Q. What improved type of air valve is now almost universally employed on all steam heating apparatus?

A. Automatic air valves. This valve is set so as to be always open when cold. When heated or when steam enters the valve it automatically closes, due to the expansion of some metal, composition, or liquid contained in the body of the valve, either of which is very susceptible to the effect of heat.

24. Q. What types of automatic air valves were first employed?

A. Among the first are the Breckenridge, Jenkins, American and Victor. The Breckenridge air valve operates by the expansion and contraction of a flat brass rod which is anchored or held rigid at each end, allowing the center, to which the valve is attached, to bend when heated, thus closing the exhaust opening to the atmosphere.

The Jenkins air valve operates by the expansion of a post made of a composition of hard rubber. This post is held rigid at the outer end by a threaded plug to which it is attached and which is screwed in and out of the body of the valve to adjust it. It is set so that the end of the composition post is slightly away from the air inlet and when heated expands against this outlet, closing the valve.

The Victor and American are quite similar to the Jenkins in operation except they are smaller in size.

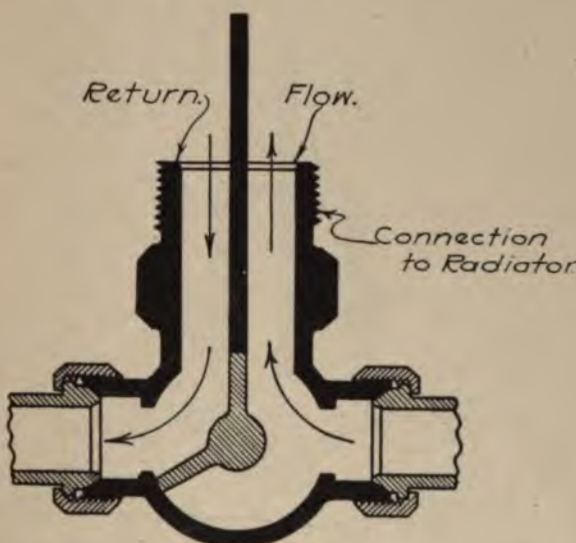


Fig. 91.—Unique Valve Open—Sectional View.

25. Q. What is the construction of the later or more recent types of air valves?

A. There are dozens of shapes and varieties to be had. Some valves of later type operate by the vaporizing of a small amount of volatile liquid which is contained in a thin copper float on the interior of the valve to which the valve stem or disc is attached. When steam strikes the float the expansion of the float, due to the vaporizing of the liquid, closes the valve by plugging the inlet shut. Other valves employ an expansion plug and in addition contain a light metal float open at the bottom. Air valves frequently give annoyance by leaking, due to a sudden rush of water in the radiator

which is forced into the air valve by the steam pressure. The light float is intended to overcome this difficulty as a sudden rush of water will raise the float and temporarily close the outlet of the valve. When the water recedes the float will drop and open the outlet to allow the escape of the air.

26. **Q. What condition should be guarded against in using automatic air valves?**

A. Air valves are frequently ruined by carelessness. They are placed on new work before the boiler has been blown off to remove the greasy scum and dirt from the system, with the result that the

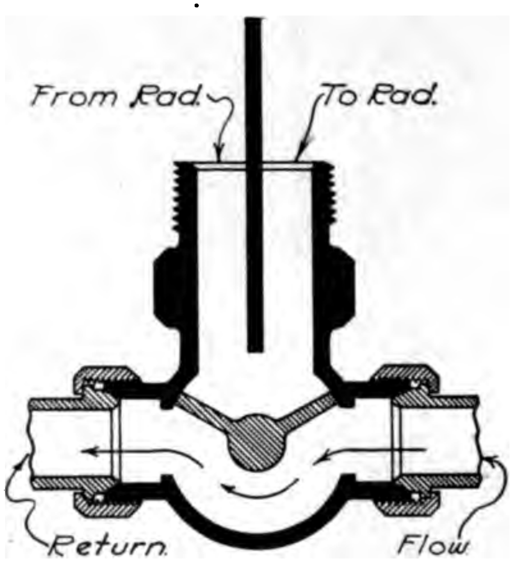


Fig. 92.—Unique Valve Closed—Sectional View.

movable parts of the valve and the small inlet and outlet become clogged with the scum or dirt.

27. **Q. How may this condition be avoided?**

A. Automatic air valves should not be placed on a heating system until it has been in operation for a period of a week or ten days and has been effectually cleaned of oil and dirt. Common compression valves should be used during this period.

28. **Q. What other cause ruins the efficiency of automatic air valves?**

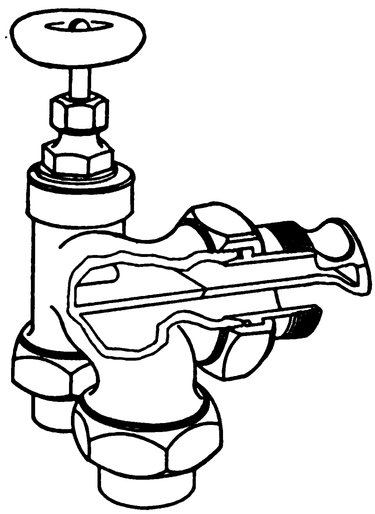


Fig. 93.—Simplex Hot Water Radiator Valve.

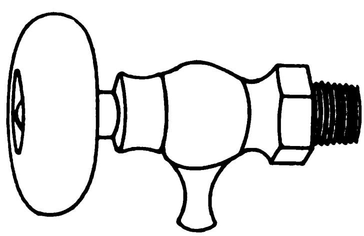


Fig. 94.—Wood Wheel Air Valve.

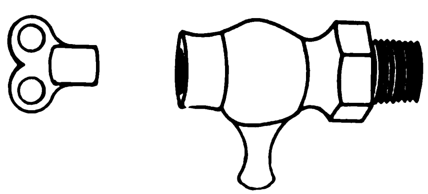


Fig. 95.—Hot Water Key Air Valve.

A. Certain types of expansion post valves are so delicately sensitive that when adjusted to close at a slight pressure of steam are ruined by being subjected to a high temperature of the steam during a period when a considerable pressure is developed for testing piping or for blowing off the boiler. The carbon post buckles with the expansion due to the high temperature and will never regain its original shape and efficiency.

29. **Q. What remedy is there for this condition?**

A. Should the valves be in position during this period they should be left open and their adjustment should be deferred until normal conditions of pressure and temperature prevail.

VACUUM, VAPOR, AND VACUO-VAPOR HEATING.

A large share of the many troubles experienced by the steam and hot water fitter in the installation of steam and hot water apparatus for heating are due to the presence of air in the heating system.

Air forming in pockets in various parts of the piping system either blocks the circulation entirely or reduces the efficiency of the apparatus by reducing the effective area of the pipe or radiating surface at the point where the air pocket occurs.

Radiators and coils are often partially air bound. In a steam-heating system this is due to the steam reaching and closing the automatic air valve before the air is entirely exhausted from the coil or radiator. Thus the air rèduces the square feet of actual radiating surface and the efficiency of the apparatus.

Air has been called the arch enemy of the steam fitter, as it is the one agency against which he must continually fight in order to meet success or in order to install successfully working heating systems.

The development, during the last twenty-five years, of improved methods of heating has resulted in the designing of many appliances for ridding the heating system of air and the troubles due to it, and these methods are variously termed vacuum heating, vapor heating, vapor-vacuum heating, vacuo-vapor heating, etc. Since the year 1882 heating engineers, contracting fitters and others have been interested in the problem of circulating steam at or below the pressure of the atmosphere. They have recognized the loss sustained by allowing the exhaust from engines, pumps, etc., to be wasted, and have evolved a method of utilizing it to the best advantage in the heating system.

The following questions and answers are intended to explain the salient features of each system and to acquaint our readers with the method of their installation and the reasons for applying or using certain special fixtures or devices.

With a knowledge of the principles of vacuum and vapor heating and an understanding of what is to be accomplished by their use it will be seen that the methods adopted are neither complex nor difficult.

1. **Q. What is meant by a vacuum?**

A. The definition given by Webster states that a vacuum is a space absolutely empty or void of matter.

2. Q. Is a bottle empty in the sense that we remove from it its visible contents?

A. No. The bottle is erroneously called empty, but it is not for the reason that when the visible contents are removed from a vessel it immediately refills with air, an invisible gas containing more or less water. This gas permeates or is forced into every opening or crevice in everything upon the face of the earth by reason of the weight of the atmosphere.

3. Q. How can a vacuum be produced and maintained?

A. By exhausting the air from the interior of a vessel either by the force of expansion of heat or steam or by employing some mechanical device, and then closing or sealing the vessel against the return of the air, or removing from it the pressure of the atmosphere.

4. Q. What is the pressure of the atmosphere, or atmospheric pressure as it is commonly called?

A. The earth is surrounded to the height of something over forty miles with a belt of elastic gas or atmosphere. This air contains more or less moisture which, owing to its weight, exerts a pressure upon the surface of the earth, and all objects upon it, of approximately 14.7 pounds per square inch.

5. Q. Is there a difference in the pressure of the atmosphere at various points upon the earth's surface?

A. Atmospheric pressure is usually based upon the pressure at sea level; the air at sea level is much more dense than at higher altitudes, consequently the weight of air or atmospheric pressure upon a mountain is much less than at the level of the sea.

6. Q. How does atmospheric pressure affect the working of a steam heating apparatus?

A. Owing to the pressure of the atmosphere water (at sea level) will not boil until a temperature of 212 degrees Fahr. has been reached. By removing this pressure entirely the water will boil at approximately 98 degrees. No steam can be produced or flow through the pipes and radiators of a heating system until there is developed a pressure sufficient to overcome that of the atmosphere.

7. Q. How does the pressure of the atmosphere affect the piping and radiation or the steam space of the heating system?

A. Through the air valve openings of the system the pressure of the atmosphere is exerted against the water in it, and therefore a pressure exceeding that of the atmosphere must be developed at the boiler to drive the air out of the system before the piping and radiators will fill with steam.

8. **Q. What is this pressure called when registered at the boiler?**

A. Gauge pressure, as it represents the pressure on the system, as indicated by the steam gauge, above that of the atmosphere.

9. **Q. What is absolute pressure?**

A. Absolute pressure is the gauge pressure shown plus 14.7 pounds, the pressure of the atmosphere. When the steam gauge registers 2 pounds at the boiler there is an absolute pressure on the system of 16.7 pounds, or 2 + 14.7 pounds.

10. **Q. Can a complete vacuum be produced on a heating system?**

A. No, this is practically impossible; in fact it is unnecessary. Any vacuum whatever shows the absence of air in the system and this is the object of all appliances used for vacuum heating; a very slight vacuum being usually sufficient to produce the desired results.

11. **Q. How does vacuum heating affect the heating system in the matter of economy of operation?**

A. In a steam heating system a large share of the fuel burned is required to create the pressure necessary to drive the air from the system. This operation must be repeated each time the system is filled with steam, or, as we commonly say, each time steam is raised on the system. With the pressure of the air removed any steam produced at the boiler immediately flows uninterrupted into the various pipes and radiators of the heating system.

12. **Q. What percentage of fuel is saved by the use of a vacuum system as compared with an ordinary steam heating system?**

A. The saving in fuel is variously estimated at from 20 to 35 per cent. This saving is conditioned largely upon the amount of vacuum maintained on the system and the consequent lower temperature at which the water will boil.

13. **Q. Is there a difference in the velocity of the circulation between a steam and a vacuum system?**

A. Steam at low pressure may flow through the system at a velocity of anywhere from 20 ft. to 200 ft. per second. The flow of steam in a complete vacuum attains a velocity of 1550 ft. per second. Thus a circulation in the vacuum heating system can be established quickly.

14. **Q. How is the vacuum on a heating system produced and maintained?**

A. The first types of vacuum systems were those used in con-

nection with exhaust heating on large installations, and on these systems it was customary to use a pump having a large cylinder, called a vacuum pump or a special type of apparatus called an exhauster to pump or suck the air out of the heating system and to maintain a vacuum. The later types of vacuum appliances, as are used for house heating, are not all mechanical. The vacuum under which many small systems are operated is created by the condensation of steam, special appliances in the way of special air valves, traps, or other devices being employed to maintain the vacuum so produced.

15. Q. **What other help to a heating system is given by vacuum pump, exhauster, or similar appliance?**

A. The return of the condensation or water to the boiler is hastened, or accelerated, as the pump or exhauster not only sucks or pumps the air, but also sucks or drains the condensation from the various coils and radiators.

16. Q. **Of what benefit is this on some types of installations?**

A. It is frequently necessary or desirable to locate radiators or coils below the water line of the system. In this event the pump or exhauster lifts the return water to a height above that of the water line in order that it may be returned to the boiler by gravity.

17. Q. **What character of piping is used for a vacuum system?**

A. Various styles of installations are used, dependent upon the character of the system employed. An important condition is that the piping be erected absolutely air tight; that the stuffing boxes of all valves be carefully packed and made tight, or that a valve of the packless variety be used, and also that all boiler trimmings should be tight fitting.

18. Q. **What is the reason for this precaution?**

A. Should air leak into the system through loose joints or loose stuffing boxes of valves any vacuum developed on the system would be immediately destroyed and the benefits of employing the vacuum appliances would be lost.

19. Q. **What other features make a vacuum system particularly desirable?**

A. The low cost of installing the system; the employment of a less amount of radiation than would be required for other systems, particularly that required for hot water heating; and the removal of all danger from frosts or leaks, the system being absolutely dry above the basement. The trouble frequently experienced from

the inability to drain long runs of piping or, as before stated, any radiation located below the water line of the boiler, is overcome and is a point of efficiency gained by the use of a vacuum system.

20. **Q. What principle is employed in producing a vacuum by the condensation of steam?**

A. Water, when converted into steam, occupies a space approximately seventeen hundred times as great as it did in the form of water, a cubic inch of water producing seventeen hundred cubic inches of steam. When, therefore, a radiator or coil filled with steam is allowed to cool, but one seventeen-hundredth part of the space is occupied by the water of condensation, the remaining portion of the space filling with air (if the air valve is open) or if the air valve is closed and all connections are absolutely tight, this space is left a void, producing a vacuum in the radiator or coil.

21. **Q. Can this vacuum be maintained continuously?**

A. It is rather hard to construct an absolutely air-tight system of piping and radiator connections, and therefore a vacuum produced on a heating system will after several hours be destroyed by leakage of air unless some device for maintaining it is employed.

22. **Q. How is vacuum measured or registered?**

A. In inches. If a tube of mercury were connected to an air valve opening of a radiator under a vacuum, the suction of the vacuum would pull the mercury a number of inches up the tube. A complete vacuum would raise the mercury 29.92 inches; therefore we speak of the result as having 29.92 inches of vacuum and under this condition the water in the system would boil at a temperature of 98 degrees.

23. **Q. Give the boiling point of water when the apparatus is under a partial vacuum?**

A. The following table will show the temperature at which water will boil from complete vacuum to a gauge pressure of 10 pounds:

BOILING POINT OF WATER.

Vacuum in Inches. Steam Pressure in Pounds.	Boiling Point of Water or Temperature.
29.92	98 deg. Fahr.
29	100 "
28	102 "
27	114 "
26	125 "
25	133 "
24	140 "

	Vacuum in Inches. Steam Pressure in Pounds.		Boiling Point of Water or Temperature.
	23		146 deg. Fahr.
	22		152 “
	21		157 “
	20		161 “
	19		165 “
	18		169 “
	17		172 “
Inches	16		175 “
of	15		178 “
Vacuum	14		181 “
	13		184 “
	12		186 “
	11		188 “
	10		191 “
	9		194 “
	8		196 “
	7		199 “
	6		201 “
	5		203 “
	4		205 “
	3		207 “
	2		208 “
	1		210 “
	0	Atmospheric Pressure	212 “
	1		215 “
	2		219 “
	3		222 “
Gauge	4		225 “
Pressure	5		227 “
Pounds	6		230 “
	7		232 “
	8		235 “
	9		237 “
	10		240 “

24. **Q. What is vapor heating?**

A. Vapor heating may be said to be the circulation of vapo or steam at a pressure slightly above that of the atmosphere This circulation is accelerated or assisted by the use of certai appliances which remove the air pressure and increase the velocit of the flow.

25. Q. What pressure is ordinarily used on a vapor system?

A. A vapor system is provided with a controlling device which prevents the steam from attaining a pressure of more than a few ounces, this appliance closing the drafts of the boiler and regulating the amount of heat from the fire.

26. Q. What advantage, if any, has the vapor system over the vacuum system of heating?

A. Practically none, except that the low temperature carried on the apparatus may be considered as an advantage. The range of temperature on a vacuum system may be from the temperature of a low vacuum to any steam pressure desired. The range of temperatures on a vapor system is that obtained from a low vacuum to practically 212 degrees, the boiling point of water.

27. Q. What is known as the vapor-vacuum system or a vacuo-vapor system of heating?

A. A combination of the principles of both vapor and vacuum heating which allows a considerable pressure to be carried on the system when desired, or the system may be operated at as low a temperature as the amount of vacuum produced will allow.

28. Q. What amount of radiation is necessary for a vacuum system?

A. Approximately 10 per cent. less than would be required for the regular type of steam heating apparatus; it being conceded that the removal of all air from the system increases the efficiency of the radiating surface about 10 per cent. and therefore decreases the amount of radiation necessary for use on an open system.

29. Q. What amount of radiation is required for a vapor system?

A. Practically the same amount of radiation as would be required for a regular hot water system of heating, the range of temperatures corresponding very closely to those of an open tank hot water apparatus.

30. Q. What amount of radiation is necessary for a vapor-vacuum or vacuo-vapor system?

A. Approximately 70 per cent. of the radiation required for the open tank hot water system or possibly 10 per cent. more than would be required for vacuum steam system. The amount of radiation required for vacuum heating would be sufficient for vapor-vacuum or a vacuo-vapor heating system, but in order to obtain the best and most economical results the system should be operated at low temperatures, and therefore a slight increase in the amount of radiation is advisable.

31. **Q. What vacuum systems were first employed for heating?**

A. The Williams, Webster and Paul systems were undoubtedly the first to be used, at least, to any great extent. Mr. N. P. Williams took out the original patents of his vacuum system in the year 1882.

32. **Q. What is the principle of operation of vacuum heating systems?**

A. The operation of a vacuum system is based upon the flow of steam and condensation from a pressure slightly above into a pressure slightly below that of the atmosphere, or into a partial vacuum. The air in the system is exhausted before turning on the steam, which then flows rapidly into the lower temperature.

33. **Q. How may vacuum systems of heating be classified?**

A. First, those systems employed for heating factories or large buildings—mechanical systems we may call them—where exhaust steam or steam at high pressure is available for heating purposes, and a pump, exhauster or other appliance is used to create and maintain the vacuum. The Williams, Webster, Paul, Van Auken and others are of this class. Second, those systems operating without pressure other than that obtained from the ordinary low pressure boiler, the vacuum being maintained by a mercury seal, hydraulic pump or other device. Among these are found the systems of the Vacuum Heating Co. (Trane), the K—M—C System (Morgan Patents), Gorton (Jenkins Bros.), Dunham (C. A. Dunham), Bishop-Babcock-Becker Co., Eddy and several others.

MECHANICAL SYSTEMS OF VACUUM HEATING.

1. **Q. Describe the Webster System of vacuum heating.**

A. On a Webster system the vacuum is produced by a pump. On the return end of all radiators or pipe coils and at the base of all risers or drainage points a motor valve having a water seal is

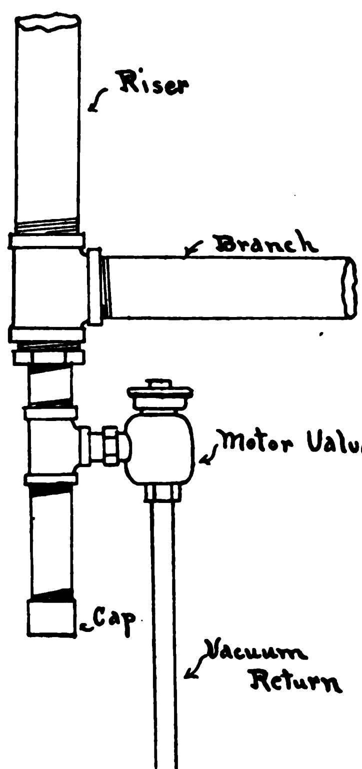


Fig. 96.—Webster Motor Valve on Riser.

placed. Fig. 96 shows the valve connected at the base of a riser, a dirt pocket being provided at each low point.

An air trap on the interior of which is a corrugated float partially filled with a volatile liquid which vaporizes at a low temperature is also used in place of the motor valve. This operates much the same as some types of automatic air valves.

When steam is turned into a radiator or coil, the air in it is forced out quickly through the motor valve or trap which closes against the steam. When sufficient condensation has accumulated to lift the float of the valve or trap, the water passes into the return and the float returns to its former position.

The original device used for many years by the Webster Company on the return end of heating units was called a thermostatic valve in which a composition hard rubber post governed the operation of the valve by expansion. The vacuum pump delivers the

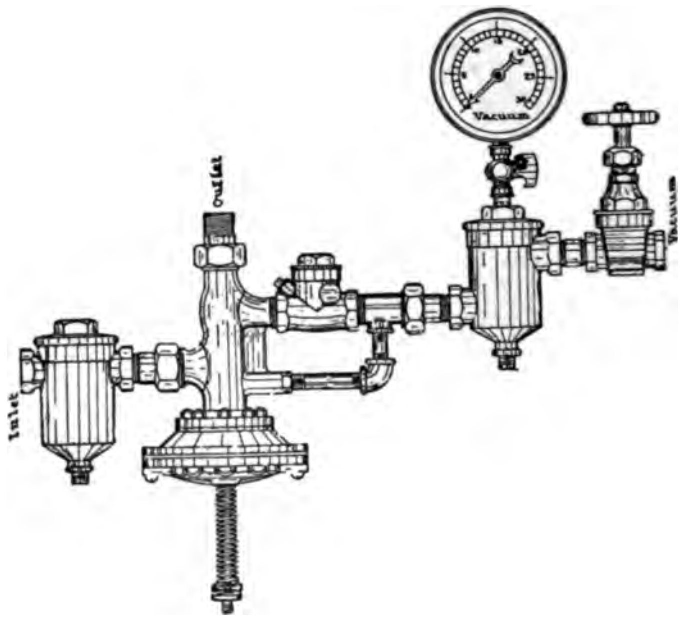


Fig. 97.—Paul Exhauster—Low Pressure.

air and condensation together to a separating tank or receiver which is vented to the atmosphere, the air passing out of this vent and the water returning to the system. In the installation of the system the usual exhaust steam specialties such as pumps, separators, feed water heaters, etc., may be used according to the character of the installation.

2. Q. Who designed and developed what is known as the Paul System of vacuum heating?

A. Mr. Andrew G. Paul, an engineer who early realized the value and effectiveness of the vacuum method of heating.

3. **Q. In what way does the method designed by Mr. Paul differ from the Webster System?**

A. The Webster system makes use of a pump which relieves the system of air and water through a single return pipe from each radiator connected into main return and air lines, hence all radiators and coils are connected as for the two-pipe system.

The Paul system makes use of an appliance called an exhauster, and the suction of this device being on the air line only the radiators may be connected one or two-pipe as circumstances require.

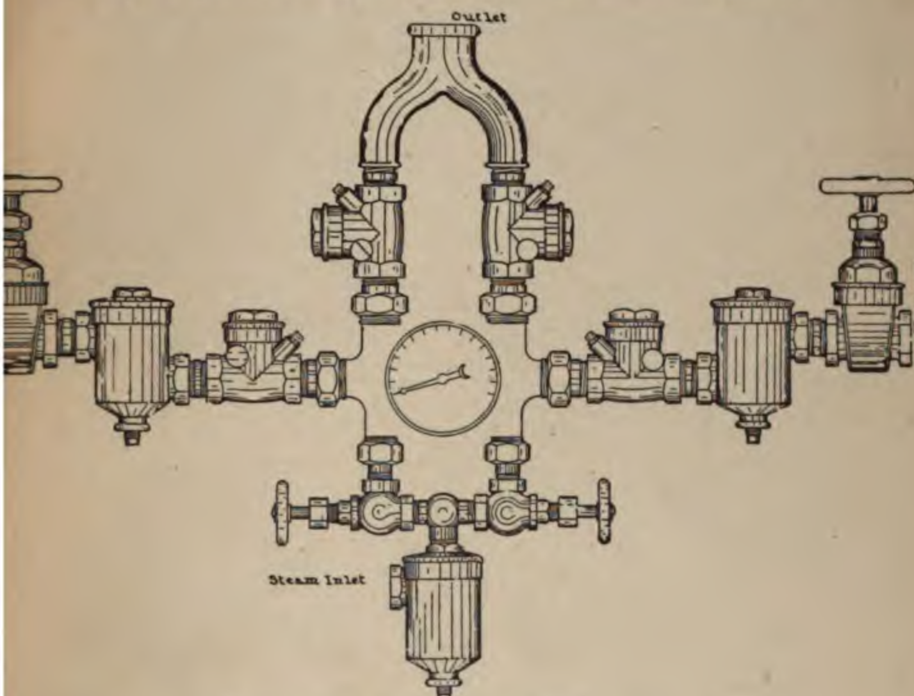


Fig. 98.—Paul Exhauster—High Pressure.

4. **Q. What form of air device is placed on each radiator or coil?**

A. A special type of automatic air valve with a drip connection called a Paul air valve.

5. **Q. How are these air valves connected to the system?**

A. By air lines. A small air pipe is connected to the drip of each air valve and these air pipes are in turn connected into a larger air pipe or air line which terminates at the exhauster in the base-

ment which produces a suction on the air lines and maintains the vacuum.

6. Q. How is the exhauster constructed?

A. In the form of a steam jet. Fig. 97 shows the construction of the exhauster as used for low pressure, and Fig. 98 the type used for high pressure or larger installations.

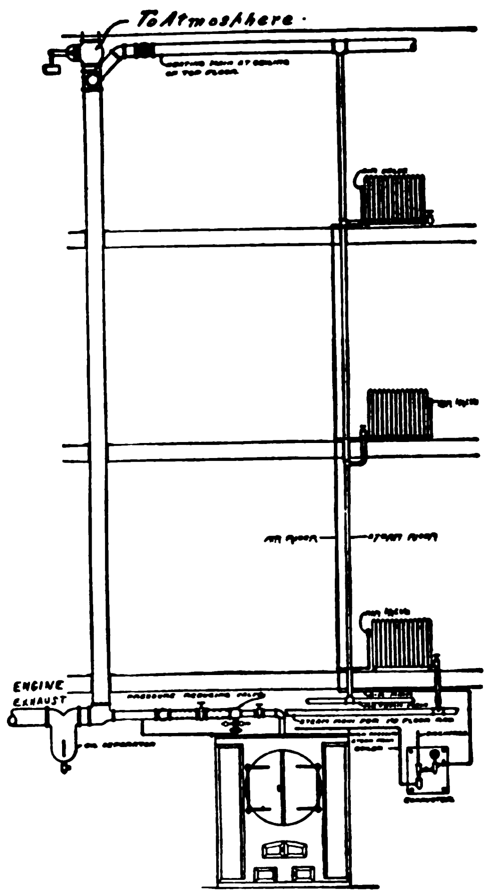


Fig. 99.—Paul System—Down Feed Exhaust.

7. Q. How does the Paul System operate?

A. The exhausting device is first started and all air is removed from the piping and radiators and the system is placed under a vacuum. Steam is then turned on and flows through the system quickly, uninterrupted by atmospheric pressure. Fig. 99 shows

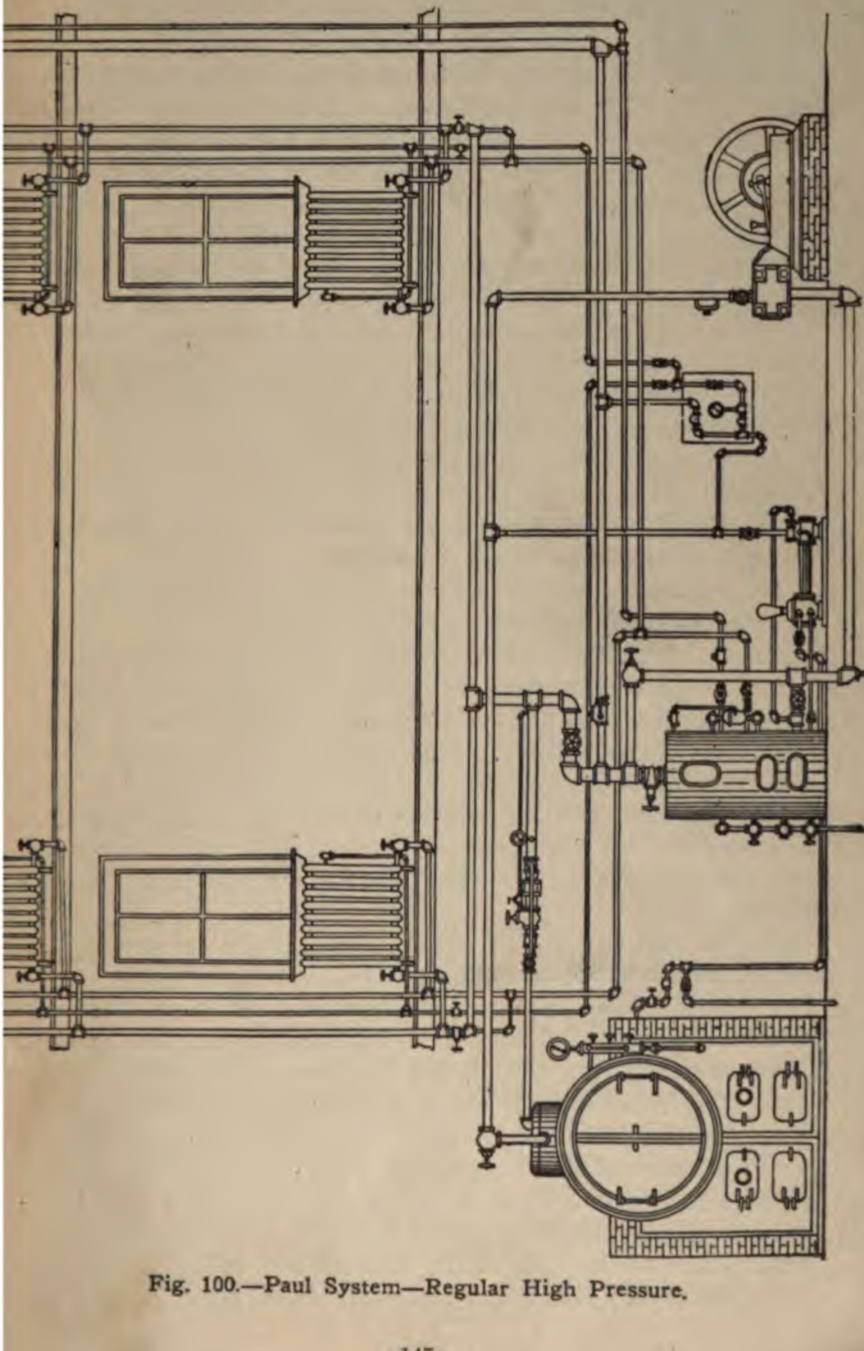


Fig. 100.—Paul System—Regular High Pressure.

the Paul system applied to a single-pipe, down-fed exhaust system, and Fig. 100 its application to two-pipe systems of exhaust heating.

8. Q. What are some of the advantages of the Paul System?

A. (a) It may be applied to any old air bound steam system that is reasonably tight so long as proper means are provided for the return of the water of condensation to the boiler; (b) unlike a pump, the exhauster or jet device has no movable parts to require lubrication or to get out of repair; (c) the economical features are astonishing. It has been repeatedly shown that where the Paul system has been installed in remodeling old systems the saving in fuel for a single season has paid the entire expense of remodeling the system.

9. Q. Are the principles used in the Paul system applied to any other systems of vacuum heating?

A. Yes, in a modified form air exhausters or aspirators are employed. Compressed air from a small air compressor driven by an electric motor can be substituted for steam when steam power is not available for the exhauster.

The vacuum may be maintained on the air lines only or the whole system may be placed under a vacuum.

10. Q. How do the Van Auken and other systems operate?

A. The heating system is drained and the system relieved of air through a special form of automatic appliance attached to the return end of the radiator. That used on the Van Auken system is called a Belvac Thermofier; other systems use air traps. Regardless of the name and construction of each appliance all of them perform the same function, viz., automatically drain the condensation and relieve the air from radiating surfaces of the heating system.

11. Q. What methods are followed in the construction of all air and condensation traps or valves?

A. Two distinct principles are used which may be called the flotation principle and the thermostatic principle, and in some valves or traps these principles are in a measure combined.

12. Q. What is the flotation method or principle?

A. This method is so called from the fact that a float is utilized in the chamber of the trap, usually a metal float, which is loose in the chamber and which rises and falls with the accumulating and relieving of the condensation in the trap, rising to allow the condensation to flow out of the radiator and falling to close the orifice or opening through the trap to prevent loss of steam into the return.

13. Q. **What is the thermostatic principle?**

A. In many respects the same as applied to the construction of automatic air valves. The operation of a thermostatic air trap depends upon the fact that steam is hotter than the condensation and that air is heavier than steam and therefore collects at the bottom of a radiator.

In some thermostatic valves an expansion post constructed with a composition of hard rubber is used. In others a volatile liquid is contained in a thin copper receptacle and in either case these expand when heated and contract when cooled. When in contact with the water of condensation the trap remains open to allow the water to enter the return. As soon as the radiator is emptied of water and steam comes in contact with the valve the composition post expands or the volatile liquid vaporizes (causing expansion) and closes the valve against the steam.

NON-MECHANICAL VACUUM SYSTEMS.

1. **Q. Are the vacuum systems known as "non-mechanical" systems operated without the use of mechanical devices?**

A. Not all of them. They seem to be known as non-mechanical systems in order to distinguish them from the mechanical as applied to exhaust or high pressure systems. Many of the vacuum systems applied to ordinary low pressure steam heating or small installations make use of mechanical devices to produce and maintain the vacuum.

2. **Q. Describe the Trane Vacuum System (Vacuum Heating Company).**

A. The Trane system is a mercurial system; that is to say, the vacuum is held by immersing the end of the air line in a pot of mercury which prevents the air from returning to the system through the air valves after once having been exhausted.

3. **Q. What is this mercurial device called and how constructed?**

A. It is called a mercury seal. The general construction is shown by Fig. 101. The air line is connected into the top of the seal, the pipe extending through the chamber of it to a point near the bottom. At the bottom of the device is a casting having a hollow cup on the top side which holds the mercury and into which the air line projects. From the side of this chamber a pipe leads to the atmosphere through which the air is exhausted.

4. **Q. What special appliances are used on the radiators for this system?**

A. Packless radiator valves should be used although a radiator valve with a well-packed stuffing box may be substituted. The radiators may be connected one-pipe or two-pipe as may be desired. The air valves used are a special type of Paul air valve having a large expansion post (Fig. 102) which has a drip connection and from the drip connection of each air valve a small air pipe connects with an air line in the basement. This air line may be carried directly under the cellar joists, terminating at a point near the boiler, where it drops and connects to the mercury seal. The air line should be carefully graded to pitch downward toward the mercury seal.

5. Q. **How does this system operate?**

A. Steam generated in the boiler at a few ounces of pressure will flow through the radiators, driving the air out of them through the air valves into the air line and finally out of the system through the mercury seal. The air cannot return through the air line and

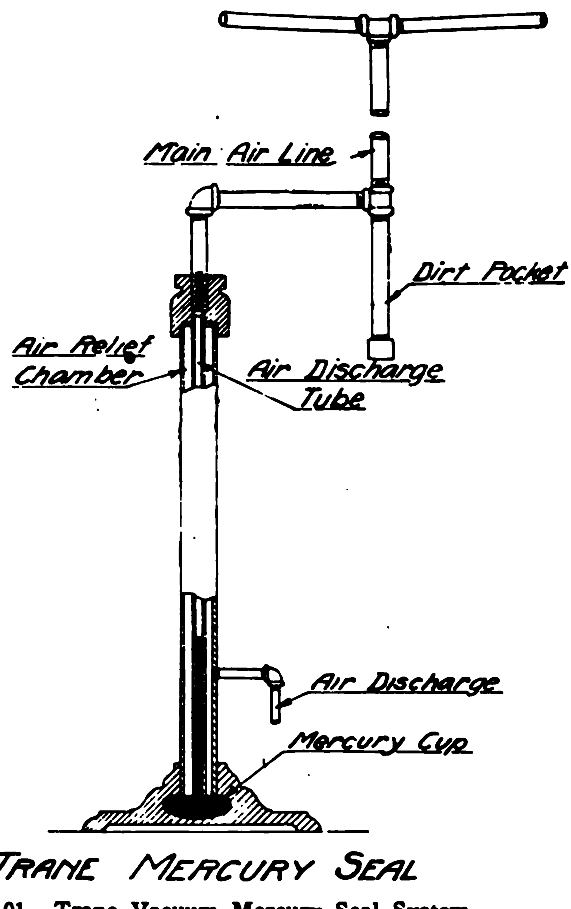


Fig. 101.—Trane Vacuum Mercury Seal System.

air valves owing to the mercury seal. By checking the fire a vacuum is produced on the apparatus which can be maintained for several hours. Should any air find its way into the system through a leak or otherwise it may again be expelled by repeating the above operation.

6. Q. What range of temperatures may be had by using this system?

A. A range of temperatures from practically 100 degrees to 250 degrees Fahr. (equaling 15 pounds pressure) may be obtained or used with this system.

7. Q. Are any other special appliances necessary for this method of heating?

A. No further appliances are required other than have been mentioned. In the installation of the system it is well to use extreme care that there is a perfect drip of all condensation into

Fig. 102.—Trane-Paul Air Valve.

the return line and back to the boiler so that all condensation may return to the boiler by gravity. A wet return system of piping is the best method to use and the connections to radiators should be made from the top of the steam main. If only one radiator is connected the vertical air line should be ¼ inch and the horizontal line ⅜ inch in size, and where two or more radiators connect into the same line the pipe should be increased to ½ inch; in the basement the air line risers are joined into a common air line ¾ inch or larger according to the size of the apparatus or the number of radiators employed on the work.

8. Q. What method is known as the K–M–C system, designed by D. F. Morgan?

A. The K—M—C system makes use of a mercury appliance similar to that employed by the Vacuum Heating Company, and in addition to this a small tank, called an accumulating tank, into which the air line connects in order to condense any vapor or steam which might enter into the return line. The air connection from the tank to the mercury seal device passes through floating checks and thence from the mercury or air seal to the atmosphere. When the accumulating tank is placed in a horizontal position the connections to checks and mercury seal are made as shown by Fig. 103. When there is sufficient head room to place the tank in a vertical

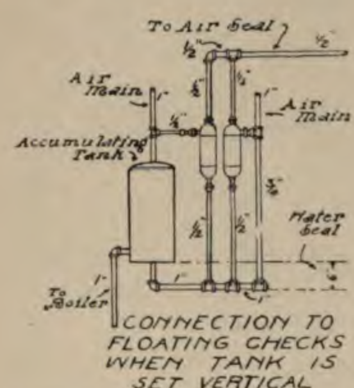


Fig. 103.—K-M-C Vertical Checks—Vertical Tank.

position the floating checks are connected as shown by Fig. 104. This illustration does not show the connection to the mercury seal.

9. Q. What device is used on the return end of a radiator as an air trap or to prevent the steam from entering the air line?

A. A special form of air valve called a retainer valve of the shape and character shown by Fig. 105 is employed in place of an ordinary air valve. This valve is of the float and expansion variety and is so constructed as to immediately close when steam enters it.

10. Q. What type of radiator valve is employed for use on a K–M–C system?

A. A special packless diaphragm radiator valve is recommended.

11. Q. How, and of what size, is the air piping installed for use with this system?

A. Practically the same as for all other air line systems. A

small pipe connects the bottom of the retainer valve with a horizontal air line, the horizontal connections being made slightly larger than the vertical connections from the radiators. In the event of the air lines from two radiators being connected together the size of piping is increased to ½ inch and the air line proper which is run in the basement may be ¾ inch or 1 inch, according to the size of the job. There should be a continued pitch of the air lines from the radiators to the point where they are connected to the accumulating tank.

12. Q. What is known as the Gorton system of heating?

A. The Gorton system of heating is a vacuum system formerly owned by the Gorton & Lidgerwood Co., now manufactured and marketed by Jenkins Brothers Co. Unlike the systems which

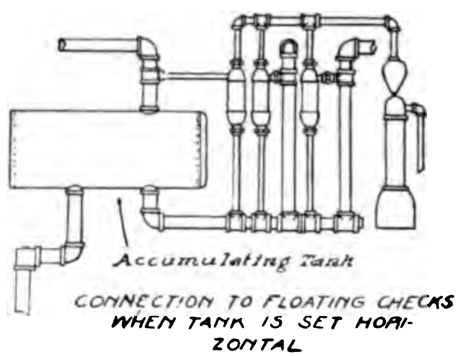


Fig. 104.—K-M-C Vertical Checks—Horizontal Tank.

have been described, the Gorton system makes use of a radiator connection at the top of a radiator, similar to a radiator connected for vapor heating, the return being taken from the bottom of the opposite end. The Gorton system is a two-pipe system. A special type of appliance called a relief valve is connected from the top of a steam main to a relief pipe on the return main and operates in the same manner as an automatic air valve. Fig. 106 shows the method of connecting the relief valve to the heating system. Its purpose is later described under the method of operating this system.

13. Q. To what type of heating installations can the Gorton system be applied to advantage?

A. The Gorton system is particularly adapted to small or

moderate sized systems in which the water returns to the boiler by gravity without the use of a pump or other mechanical device, and unlike a number of the non-mechanical vacuum systems the return from the system should be the ordinary dry return, dropping down at the boiler in the usual manner and a loop seal is used at the end of the main.

14. **Q. What type of radiator valve is employed on a Gorton system?**

A. A fractional, or graduated supply, radiator valve is used on each radiator or unit of radiation, by the use of which the

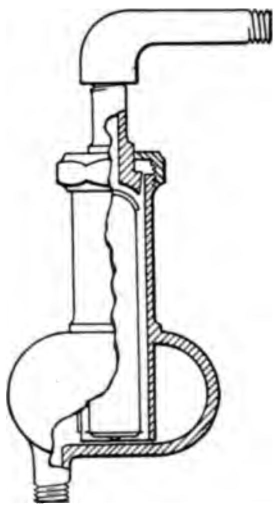


Fig. 105.—Retainer Valve—K-M-C System.

amount of steam or vapor supplied to each radiator is limited or controlled.

15. **Q. What type of valve or trap is employed on the return end of a radiator for this system?**

A. A special valve called an automatic drainage or impulse valve is placed at the end of each radiator to connect it with the return, the seat of which is made considerably smaller than the pipe connection. Fig. 107 shows the construction of this valve. The seat is inserted at such an angle as to prevent wedging or sticking and will pass the ordinary dirt in the system without trouble. A cone projects from the disc of the valve into the opening of the seat and a counterweight is applied in such a manner that

they both act to render the opening of the valve very gradual for differences in pressure.

16. **Q. How is the air removed from the system?**

A. The air removal is accomplished by means of the automatic relief valve illustrated by Fig. 108, which is acted upon by the varying pressures created in the return pipe by reason of the presence of air or steam.

17. **Q. What type of radiators are used for this system?**

A. Radiators of the hot water type having top and bottom connections through them.

18. **Q. How does the Gorton system operate?**

A. Steam is generated and enters the main, the friction of its

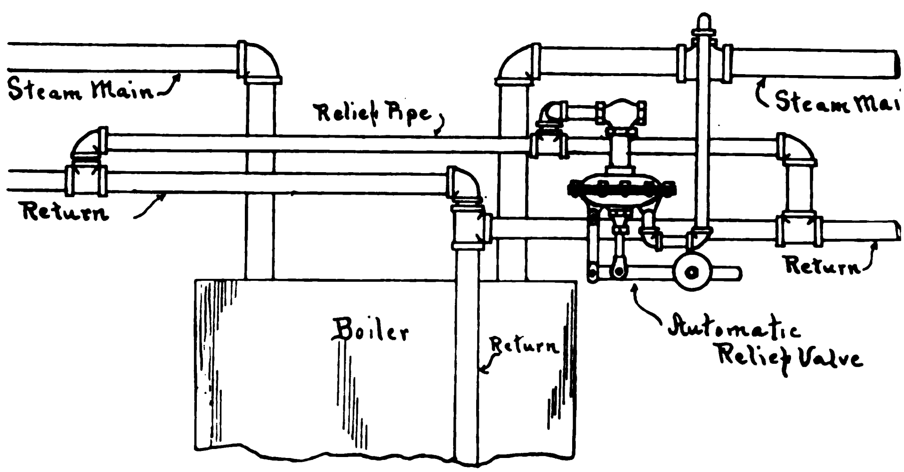


Fig. 106.—Method of Connecting Relief Valve—Gorton System.

movement causing a slight pressure in the boiler, which communicates to the under side of the diaphragm of the relief valve and closes the air outlet, which remains closed until the pressure passes into the radiators and opens the drainage valve, compressing the air in the return. The relief valve then opens and exhausts this air from the system, the flow continuing until all air passes out of radiators and return pipes and the pressure in the return is sufficiently reduced to allow the relief valve to close. By reducing the weight upon the relief valve a little more than is necessary to close it, and leaving it just heavy enough to open when the system is cooled down, it is very easy to keep the return pipes partially filled with air at all times. This air flows along with the steam and

cools at the relief valve ready to discharge whenever an additional amount of air is returned from a radiator. Owing to the top connection of the radiator and the graduated supply valve used, any radiator may be partially heated, admitting sufficient steam or vapor to the radiator as may be required by the condition of the weather.

19. Q. What is known as the Dunham system of vacuum heating?

A. The Dunham vacuum system is an air line system in which all air is returned to a receiving tank located above the boiler. A special form of radiator or air trap is the distinguishing feature of the Dunham system, a sectional view of which is shown by Fig.

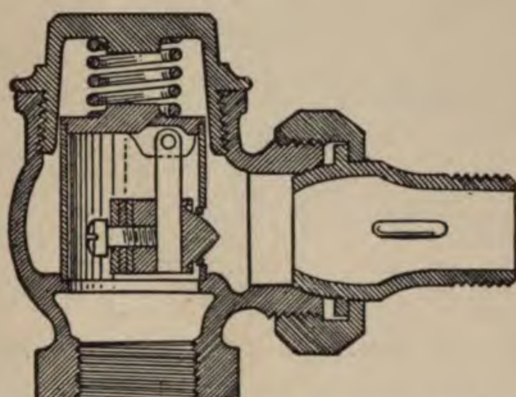


Fig. 107.—Impulse Valve—Gorton System.

109. These traps are made for a straightway or angle connection. The trap permits the discharge of all water of condensation and air from the radiator without the loss of steam. The end of a pipe loop called an equalizing tube extends into the boiler to a point level with the water line. On the end of this tube is a bell shaped attachment. This equalizing tube is used to keep the pressure in the boiler from communicating itself to the receiving tank until such a time as the water of condensation in the tank (due to the condensation of steam from the boiler) will be sufficient to cause the water in the boiler to lower below the bell of the equalizing tube. At this moment steam from a dome of the boiler rushes

up through the equalizing tube, the end of which is now open in the steam dome, and into the tank; steam entering the tank closes an air valve located at the top and the swing check valves on the return lines connected to the tank, thus equalizing the pressure in the tank with that in the boiler and the water which has accumulated in the tank flows back into the boiler through the check valves at the bottom return openings, raises the water line in the boiler and seals the bottom of the equalizing tube.

The tank is now full of steam and as this steam condenses a vacuum is formed in all of the return lines. Fig. 110 shows the method of making connections to the boiler and tank.

20. Q. What method is used by the Bishop-Babcock-Becker system of vacuum heating?

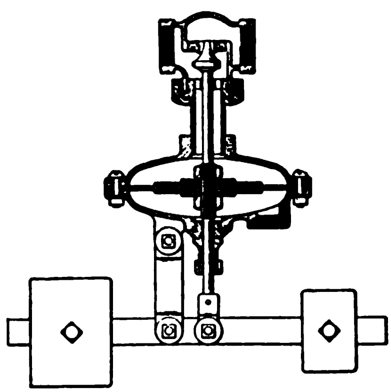


Fig. 108.—Automatic Relief Valve—Gorton System.

A. The Bishop-Babcock-Becker system is a vacuum system installed with the regular air line method of exhausting the air. To the end of the air line there is attached an hydraulic pump which is so adjusted as to create and maintain any desired vacuum on the apparatus. It produces and maintains the vacuum positively, it being equipped with an automatic cut-off so that when the degree of vacuum has been attained for which this cut-off is adjusted the pump stops, and when the vacuum drops slightly below this point the pump automatically begins to operate, continuing to suck the air out of the system until the desired degree of vacuum is again produced.

21. Q. What method of piping is used for this system?

A. The method of piping employed is similar to that used for the one-pipe system of gravity steam heating. Connections to radiators should be made in such a manner that all condensation

will return from the radiators to the main through the supply branches, and the drip from the main should convey the condensation to the boiler by gravity. An automatic air valve having a drip connection is placed at the end of each radiator and the air line connections from this drip to an air line main in the basement which terminates at the pump connection. A condensing apparatus is placed near the pump to condense any steam that may be drawn into the air line. Fig. 110 shows the pump and condenser.

22. **Q. What type of radiator valve is used with the Bishop-Babcock-Becker system?**

A. Any good type of a tight radiator valve may be used although a packless radiator valve is preferred.

23. **Q. What amount of vacuum should be carried on this system?**

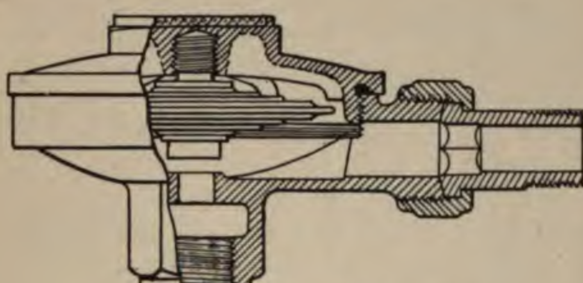


Fig. 109.—Dunham Air Trap.

A. It is usual to operate the pump until there is about 7 inches of vacuum on the system and the automatic cut-off on the pump should then be set to maintain this vacuum.

24. **Q. What amount of water pressure is necessary for the operation of the hydraulic pump with this system?**

A. This pump can be used where the water pressure is 20 pounds or more and is built in various sizes suitable for any size of heating apparatus.

25. **Q. How does the Eddy vacuum system operate?**

A. The Eddy system makes use of a combined receiving tank, exhausting and vacuum valve. The system is particularly an air line system, the air lines being installed in the usual manner.

26. **Q. Are air valves used with this system?**

A. Air valves are not used. In place of air valves a small appliance known as a retarder is introduced into the air vent opening of each radiator and the air line is connected from the bottom of each retarder.

27. Q. How is the vacuum produced which operates the system?

A. By the condensation of steam, the exhausting and vacuum valve sealing the system to the atmosphere and preventing the

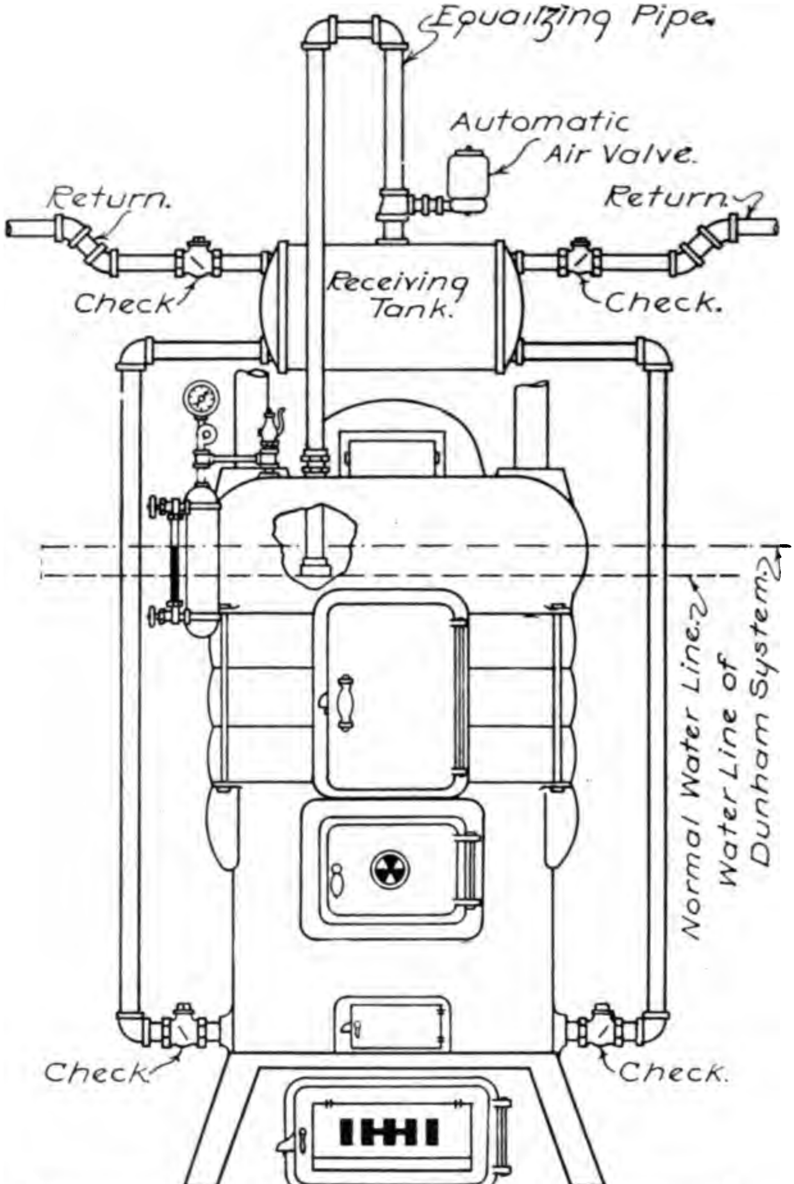


Fig. 110.—Connections to Boiler and Tank—Dunham System.

return of air into the system after it has once been exhausted. This operation is entirely automatic. It may be operated with steam or vapor at a temperature of 160 degrees or at a pressure of two pounds or more if desired. The range of temperatures obtained in its operation makes the system particularly serviceable.

28. Q. What other vacuum systems are in use at the present time?

A. There are several types of vacuum systems known and used locally in certain sections, each of which, however, embodies some one of the principles described and illustrated in the foregoing systems. Many of these systems are unknown except in a restricted territory.

To properly classify the following systems would be a difficult matter. We have divided them into three classes, viz.: Vapor systems, vapor-vacuum or vacuo-vapor systems, and atmospheric or modulated systems, although some of them might properly be considered in the non-mechanical vacuum class.

Some of the so-called vapor systems make use of vacuum principles and some of those called vacuum-vapor are operated principally as vapor systems.

It would seem that in naming each system the inventor or designer, in many instances, sought to adopt a name which would distinguish his particular system from others of a similar character. The Broomell and Mouat systems are called "Vapor" systems, and that of the Vapor Regulator Company an "Atmospheric Vapor" system. The Moline, Kriebel and Kinealy systems are known as "Vacuum-Vapor" systems, and the Dunham non-mechanical system as "Vacuo-Vapor."

Other systems such as the "Adsco" (American District Steam Company) are known as "Atmospheric" systems, and that of the Warren Webster Company as a "Modulating" system.

Possibly it is sufficient to say that the vacuum systems mentioned and those described on the following pages represent the very latest ideas and practice in the circulation of steam or vapor at or below the pressure of the atmosphere or at a few ounces above atmospheric pressure, and their exact classification is not so important a matter.

The one feature common to all of these systems is that no air valves of any kind are employed on the radiators, all air being removed through an air or return line to the basement and exhausted from the system through some device installed for this purpose.

VAPOR SYSTEMS.

1. **Q. What system of vapor heating may be called the original vapor system?**

A. The Broomell system was no doubt the first vapor system to be extensively used.

2. **Q. What method of piping is employed with this system?**

A. Any good method of piping, where a dry line is assured, will prove satisfactory. The sizes of mains and branches are much smaller than those required for an ordinary steam heating system. The return connections from the radiators are all ½ inch and where two are joined together the connection should be made ¾ inch. The size of the main and return line is proportioned according to the size of the installation.

3. **Q. What type of radiators is used with the Broomell system?**

A. The hot water type, having the supply tapping at the top of one end; the return tapping is usually at the bottom of the opposite end.

4. **Q. What amount of radiation is required for the Broomell vapor system as compared with other methods of heating?**

A. About the same as for an ordinary hot water heating apparatus. However, as with all other systems of heating, the best results are obtained from the operation of the system when an adequate amount of radiating surface is installed. The system being very sensitive it is necessary to use only as much of the radiation provided as may be necessary to supply the desired temperature in the room.

5. **Q. How are the radiators connected?**

A. At the supply end a special type of radiator valve called a quintuple valve is used and is so named from the fact that each valve has five holes or ports through the seat, and the handle which opens and closes the valve may be moved to open or close one, two or more of these ports as desired. At the return end of the radiator joining it to the return line is placed a special form of union elbow. Fig. 112 shows a sectional view of the valve and Fig. 113 the union elbow.

6. **Q. For what reason is the special type of radiator valve employed?**

A. In order to admit to the radiator only as much vapor as is required to give the necessary amount of heat. The radiator heats downward, the upper part being first filled with vapor by opening the valve one port and as the valve is opened further the vapor in greater quantity flows into the radiator, heating it further and further toward the bottom until, if desired, the entire surface of the radiator is available for warming.

7. Q. **How is the Broomell system regulated?**

A. An important part—possibly the all important part—of

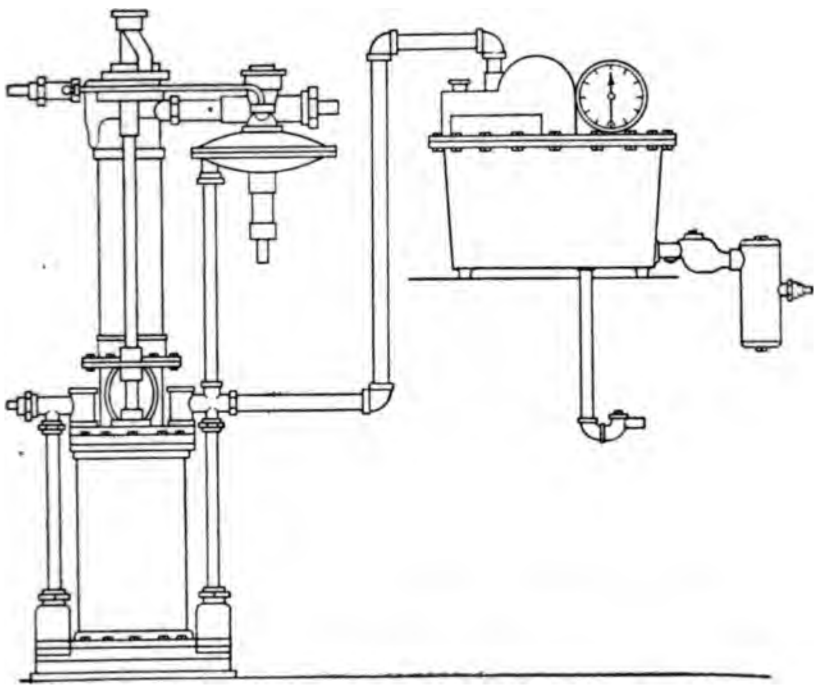


Fig. 111.—Pump and Condenser—Bishop-Babcock-Becker System.

the Broomell system is the combined receiver and regulator. This controls the draft doors of the boiler and controls the amount of heat furnished to the system.

8. Q. **What is the operation of this receiver and regulator?**

A. It is connected to the boiler and piping system as shown by Fig. 114. From the top of the receiver the air line is connected to a condensing radiator usually composed of several sections of indirect radiation suspended below the ceiling of the basement.

The receiver operates the draft doors of the boiler by reason of a copper float moving up and down in the receiver according to the expansion of the water, a chain being attached from the float to the draft doors. If the draft door is allowed to remain open in such a manner that the chain from the damper regulator will not operate to close it, the water in the receiver will rise until the copper float engages with and lifts a lever connected with a relief valve which opens the valve and relieves the system of the accumulated pressure.

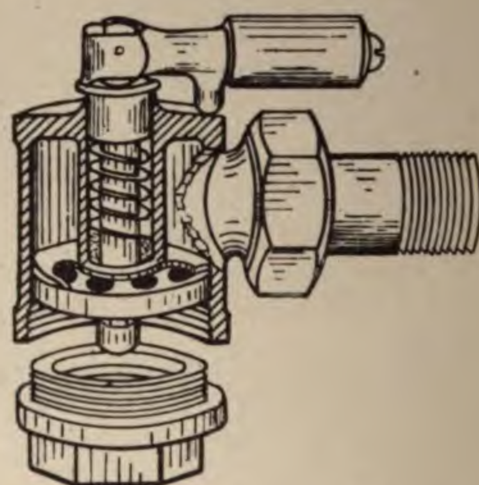


Fig. 112.—Quintuple Valve—Broomell System.

9. Q. **What pressure is ordinarily carried on the boiler with this system?**

A. It is usual to set the appliance to open the relief valve at from 7 to 10 ounces of pressure.

10. Q. **What is known as the Mouat vapor heating system?**

A. The Mouat vapor system is not unlike the system already described. Radiators are installed of similar capacity and are connected the same as on the system already described. At the return end of the radiator a special union elbow connection is provided which prevents the vapor from entering the return piping. A special form of a pressure regulator is used on the boiler which

operates the draft doors and the usual amount of pressure carried on the system is from 5 to 8 ounces. A fractional radiator valve is used on the supply of each radiator; it is placed at the top of one end, the condensation and air being exhausted through the opposite end of the radiator. Fig. 115 shows the character of the installation of the system.

11. **Q. How is the piping installed for the Mouat vapor system?**

A. The supply main is run in a similar manner to the one-pipe system of steam heating, the drip at the end of each supply line returning wet to the boiler, the mains pitching from the boiler toward this drip connection. The return and air line is vented into the smoke flue and a swing check is employed at a point where it is connected into the return of the boiler.

12. **Q. What is the principal feature of the Mouat vapor system?**

Fig. 113.—Union Elbow—Broomell System.

A. The Mouat regulator. The regulator or method of regulation is the principal feature of all vapor systems. In other respects the system differs but very little from all systems of a similar nature.

13. **Q. Describe the installation of the Trane system of vapor heating.**

A. The Trane system is installed in quite the usual manner for vapor heating. A supply pipe with branch connections conveys the vapor through riser connections to the radiators, the supply being connected into the top of the radiator. The return may be connected from the bottom of the opposite end or in the case of second or upper floor radiators the return may be connected from the bottom of the supply end, making it more convenient for running the risers. The Trane system is regulated by a very sensitive diaphragm regulator which is so adjusted as to operate the draft doors at a pressure of from 1 to 6 ounces. The return water of condensation and the air in the system are connected into a receiver,

the water returning by gravity. At the receiver the air and water separate, the air passing through the opening at the top of the receiver and the water returning to boiler through a pipe connecting with the return opening. A float on the inside of the receiver makes it possible to return the water to the boiler at any time and prevents the water from leaving the boiler even under a pressure of several pounds. Fig. 116 shows the appearance of the receiver.

14. **Q. How is the air exhausted from the radiators?**

A. A union elbow connection is made at the return of each

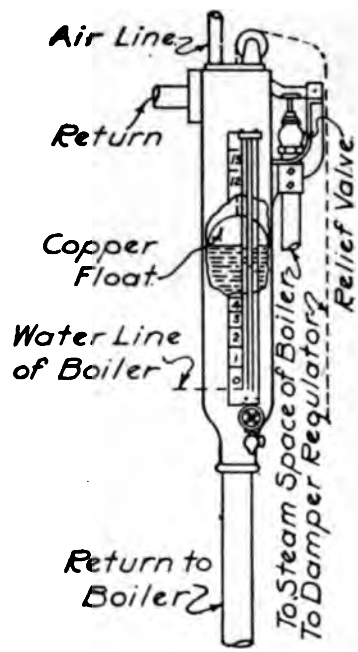


Fig. 114.—Receiver and Regulator—Broomell System.

radiator. The spud of the elbow connecting to the radiator is closed with the exception of two small openings, one at the top and one at the bottom. The top opening is small for the escape of air and the bottom opening is made larger for the escape of water. The bottom opening is supposed to be completely filled with water at all times, the size of the hole being sufficient to allow the condensation to pass from the radiator to which it is attached.

15. **Q. How does the Trane system operate?**

A. When a pressure of a pound or more is attained at the

boiler, and the receiver is opened to the atmosphere, water will stand higher in the receiver than in the boiler, the same as would be the case with water in an ordinary water column without a top equalizing connection. As the pressure increases the level of the water rises in the receiver until the float closes the upper open-

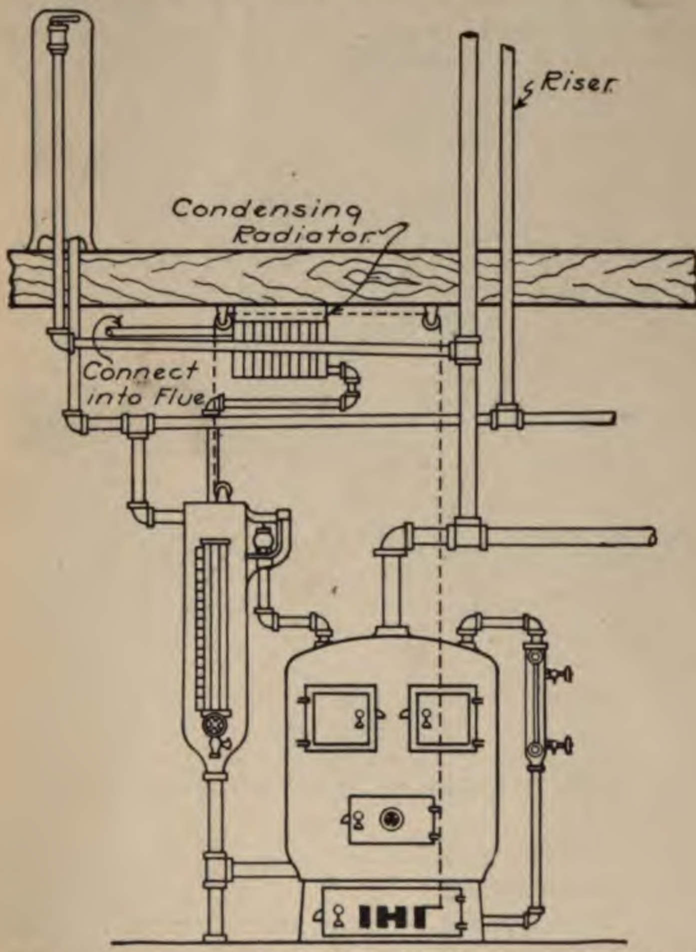


Fig. 115.—Broomell Receiver and Regulator Connected to System.

ing. At this time the system is filled and the pressure throughout becomes more uniform, there being so little difference between the pressure in the boiler and receiver that the water of condensation returns to the boiler by gravity. It is intended that sufficient

radiation be installed to warm a building with one or two ounces of pressure or with vapor at a slight pressure above that of the atmosphere. The various appliances used with the Trane system are intended to be so carefully adjusted as to operate the system at this small pressure. Vapor in the radiators is quickly condensed and returning to the receiver at the boiler is separated from the air and enters the boiler to be again quickly warmed. At the same time the system is so constructed that adjustment may easily be

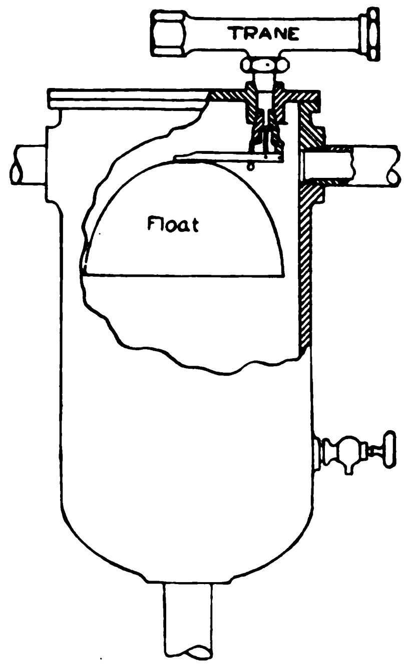


Fig. 116.—Receiver Trane Vapor System.

made for excessively cold weather. Fig. 117 shows the general construction of the system.

16. Q. **What types of radiators and valves are required for the Trane system?**

A. The radiators should be of the hot water type, having a top and bottom connection, and the radiator valve used should be a graduated radiator valve, or, as they are sometimes called, a fractional valve, in order that the amount of vapor admitted to the radiator may be carefully and easily regulated. As with other vapor systems sufficient vapor may be admitted to warm only

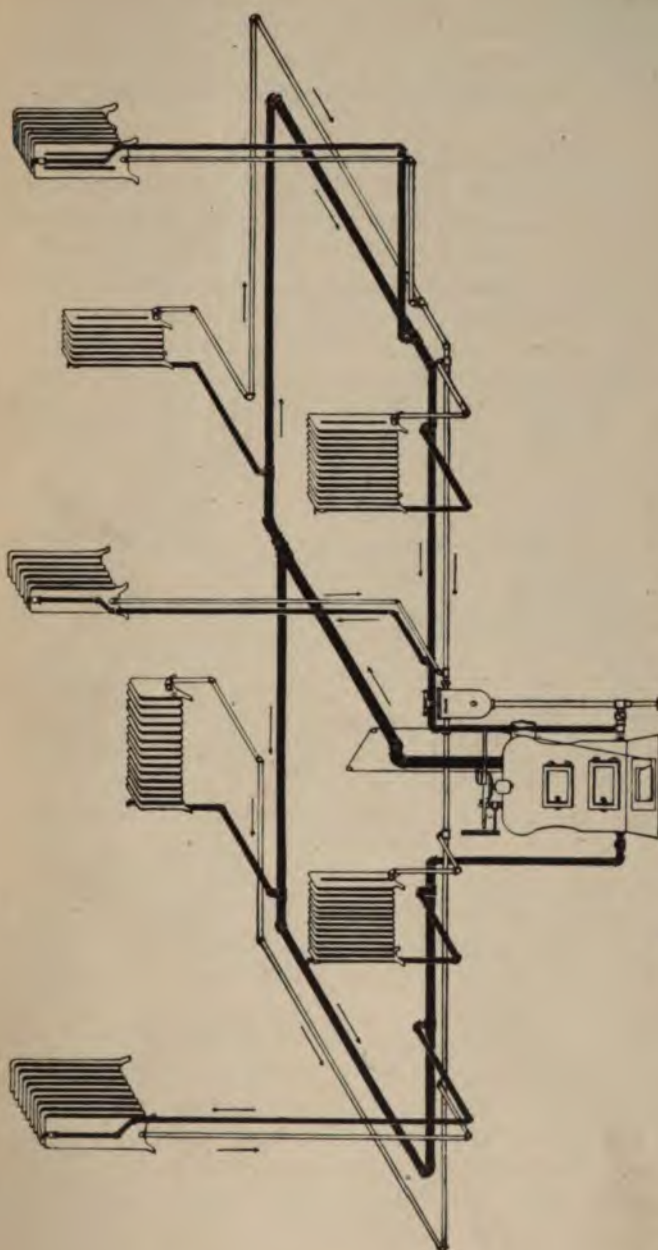


Fig. 117.—Showing Installation of Trane Vapor System.

the upper portion of the radiator, or one-half or three-quarters of its surface may be used as required, the amount of surface warmed always being conditioned by the amount of vapor admitted to it.

17. Q. **Describe the vapor system of the Vapor Regulator Company.**

A. The method of piping employed for use with this system is exactly similar to those already described. The features of the system are the manner of regulating the pressure by a float type of vapor regulator; the manner of draining the radiator of air and condensation through what is known as a bushing trap which may be used on the return end of all drop hub radiators, or through an appliance called a union trap which is used on the return end of any style of radiator. This trap is made in both straightway and angle patterns. The construction of it is not unlike the

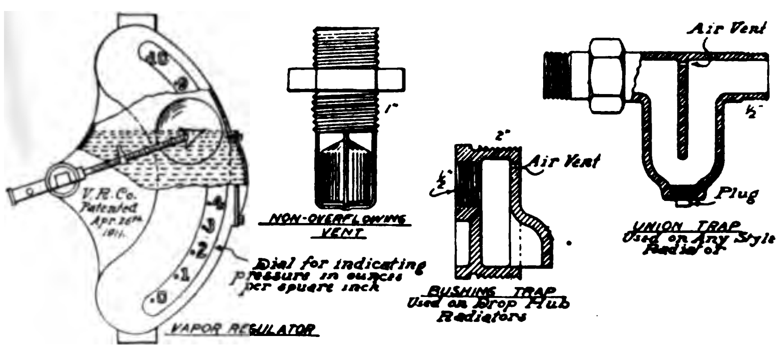


Fig. 118.—Regulator, Non-Overflowing Vent and Traps—Vapor Regulator Co.

special union elbow employed with the Broomell system. The idea of both bushing and trap is to prevent the loss of vapor into the return line. Fig. 118 shows a detail of the regulator, non-overflowing vent and traps.

One feature of the piping as used with this system is different from that employed on the ordinary system of vapor heating. A vent pipe is taken from the piping connection at the top of the receiver to a point on the second floor, where it is connected into the smoke flue. On this pipe is placed a non-overflowing vent, the purpose of which is, as its name suggests, to allow the air to be exhausted from the system without the possibility of the water overflowing through the vent pipe should a more than ordinary pressure be generated at the boiler. The radiators are connected

and the graduated supply valve employed precisely as with other vapor systems. Fig. 119 illustrates the method of installing this system.

18. **Q. What size of piping is recommended for use with this system?**

A. Pipe sizes for this system are not different from other vapor systems and the following table will give the sizes recommended for various quantities of radiation with mains of various lengths. In the event of an increase in the length of main beyond that given in the table the next larger size of supply and return is recommended.

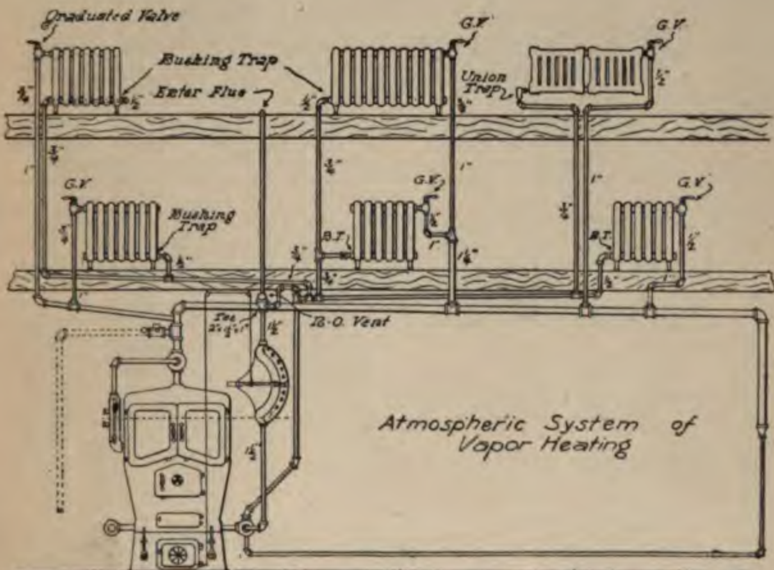


Fig. 119.—Method of Installing Atmospheric System—Vapor Regulator Co.

19. **Q. Describe the Moline system of vacuum-vapor heating.**

A. The Moline system employs both vapor and vacuum principles designed to operate without the use of pumps or traps and in its general construction is in many respects similar to the ordinary vapor heating systems. The two-pipe method of connecting the radiators is used with the Moline system, one pipe conveying the vapor to the radiators and the other taking the air and water from the radiators; the principal difference between this and other systems being the method of separating the air from the return

water and of keeping the air out of the system by placing it under a partial vacuum.

20. **Q. How is the air exhausted from a Moline system?**

A. Through an automatic air trap which is a compound air trap and vacuum valve. This is placed on the system at a point near the boiler and is in reality an automatic air valve of such size, however, that it is very quick and efficient in expelling the air, and also prevents loss of steam.

21. **Q. How does this air trap operate?**

A. The operation of the trap is caused by the expansion and contraction of a small quantity of air contained in an open bottomed float. The usual automatic air valve operates by the expansion and contraction of a small expansion post or by the vaporizing of volatile fluid confined in a small float. These principles are not used on the Moline air trap.

SIZES OF SUPPLY, RETURN AND DRIP PIPES—VAPOR HEATING.

Square Feet of Radiation.	Main Supply.	Dry Return.	Drip.	Length of Pipe.
100	1¼	¾	¾	30
175	1½	1	¾	60
300	2	1¼	¾	90
500	2½	1¼	1	120
800	3	1½	1	150
1,100	3½	1½	1	175
1,600	4	2	1¼	200
2,500	5	2	1¼	225
3,600	6	2½	1¼	250

22. **Q. For what purpose is the Moline vacuum valve employed?**

A. The Moline vacuum valve seals the piping and radiators against the return of air after it has once been expelled from the system.

23. **Q. In the removal of air from the Moline system what other appliances are required other than the air trap?**

A. An ejector and condenser. A radiator (usually one of the first floor radiators) is used as a condensing radiator on larger installations; on smaller installations a coil of pipe is used on the ceiling of the basement. A connection from the steam main is made to this coil or radiator. Fig. 120. The appliance called an ejector is placed on this connection and the return from the loop or condensing radiator is connected to the air trap. The steam passing

through the ejector causes a suction which draws the air from the system and delivers it to the air trap, from which it is exhausted to the atmosphere. Fig. 121 shows the method of installation and position of the various fixtures.

24. Q. What is the operation of the Moline system?

A. The first heat from the boiler expands the air and forces it from the system through the condenser, ejector and air trap. As soon as vapor is formed in the boiler it flows through the system and reaching the ejector flows through it with sufficient velocity to draw the air from the air main. This action reduces the air pressure in the radiators and causes a more rapid circulation of the vapor to them. After all radiators are thoroughly heated a small quantity of vapor passes through the ports or openings in the return valves to the condenser. When the condenser becomes heated the vapor travels on to the air trap. After reaching the

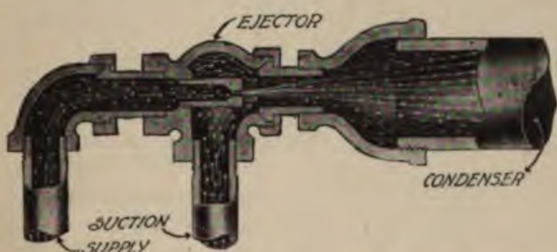


Fig. 120.—Ejector and Condenser—Moline System.

air trap it expands a small volume of air in the trap float and closes the opening of the air trap so that no vapor can escape. When the steam pressure is removed at the boiler or the system allowed to cool the air trap cools and opens up, but the vacuum valve closes tightly and prevents the return of air, with the result that the system is placed under a partial vacuum and the heat given off at the radiators condenses as long as there is any vapor in the system. When the drafts of the boiler are again opened and a slight pressure is raised on it above that of the atmosphere the vapor or steam can pass without interruption into all of the radiators the same as on a vacuum installation.

25. Q. What sizes of pipes are used in the installation of a Moline system?

A. The mains and returns should be sized as follows:

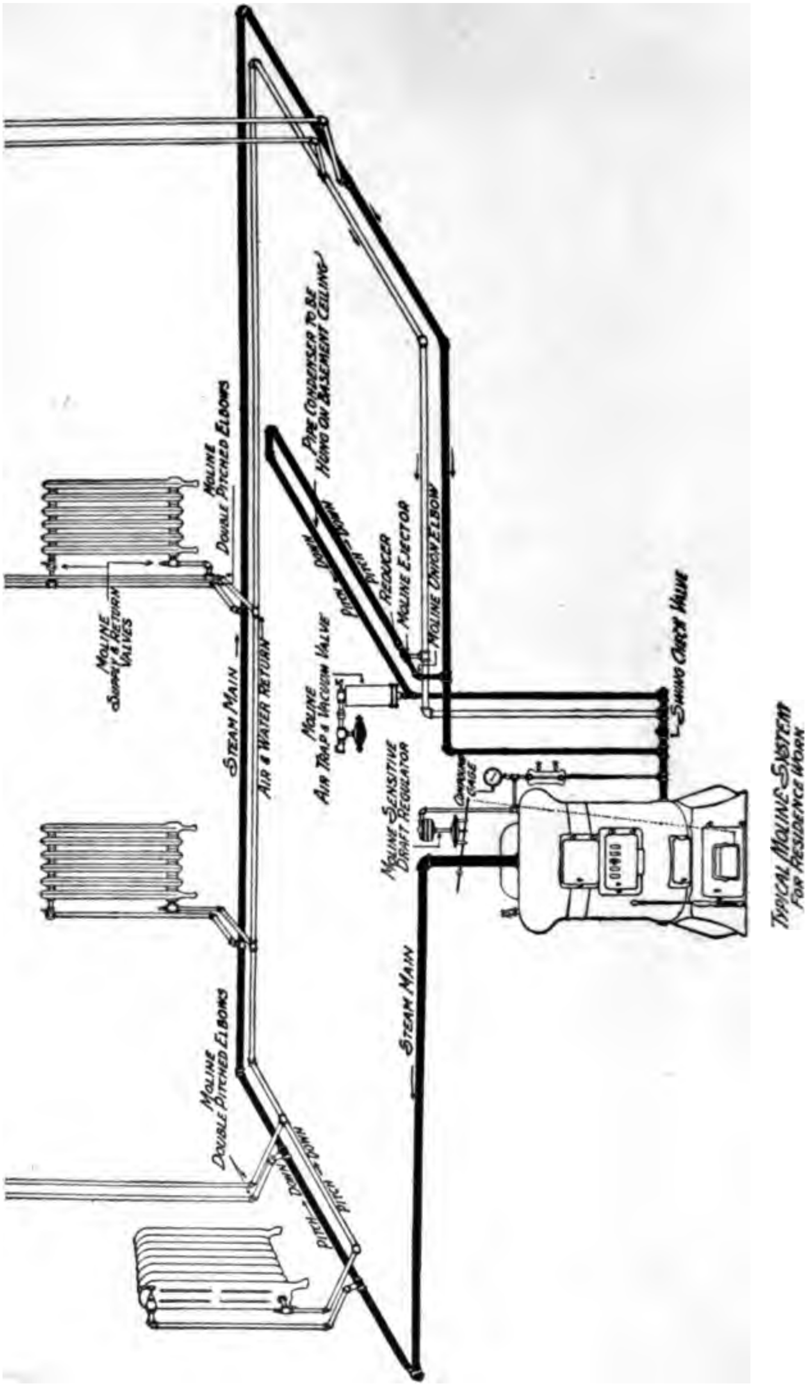


Fig. 121.—Method of Installing Moline System.

Square Feet of Radiation.	Size of Main.	Size of Return.
100 to 300 sq. ft.	1½ inches	1 inches
300 to 600 "	2 "	1¼ "
600 to 1,000 "	2½ "	1½ "
1,000 to 1,400 "	3 "	2 "
1,400 to 1,800 "	3½ "	2 "
1,800 to 2,500 "	4 "	2 "
2,500 to 3,500 "	4½ "	2½ "
3,500 to 5,000 "	5 "	2½ "

SIZES OF BRANCHES AND RISERS.

¾ inch will supply	60 sq. ft.	in one radiator	½ inch return
1 " " "	100 "	" " "	½ " "
1¼ " " "	150 "	" " "	¾ " "

26. **Q. What is known as the Kriebel system of heating?**

A. The Kriebel system may be called a vapor system or a vacuum-vapor system as its installation combines both vapor and vacuum principles of heating.

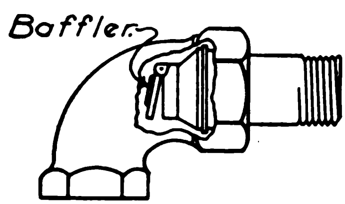


Fig. 122.—Baffler—Kriebel System.

27. **Q. How is the Kriebel system installed?**

A. The arrangement of the piping is very similar to that required for the ordinary low pressure gravity return steam job. The connections to radiators are made two-pipe, the supply being connected at the top of a radiator and the return and air line connected at the bottom of the opposite end:

28. **Q. What size of piping is necessary for this system?**

A. As the Kriebel system operates at a temperature below atmospheric pressure or slightly above it the piping should be the size ordinarily employed for vapor heating, the best results being obtained where a carefully constructed system of piping has been installed.

29. Q. What method is used in connecting the radiators for this system?

A. A graduated supply valve is used in order to more easily govern the amount of vapor or steam admitted to a radiator, and on the return end, in order to prevent the loss of vapor or steam into the return line, there is placed a union elbow in which a small baffler is employed; the baffler being quite similar to the clapper

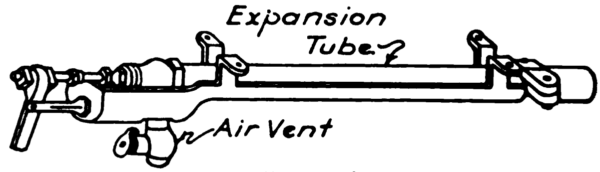


Fig. 123.—Controller—Kriebel System.

of an ordinary swing check valve, but lightened to such an extent that a very small weight of water will operate it. When sufficient condensation has collected to open the baffler the water is passed through into the return line, when it immediately closes against the steam or vapor. Fig. 122 illustrates this elbow.

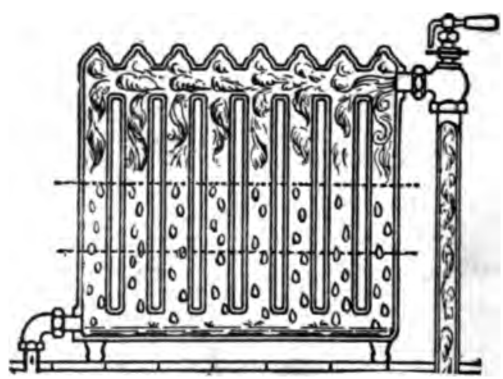


Fig. 124.—Circulation Through Radiator—Kriebel System.

30. Q. How is the air expelled from a Kriebel system?

A. Through an appliance known as a vapor-vacuum controller. This controller is in reality an expansion air trap composed of a brass expansion tube and valve held in an iron frame which is attached to the ceiling of the basement at a point near the boiler. This controller has an adjusting device on the valve, a spring holding the seat in place, and there is also provided an air outlet

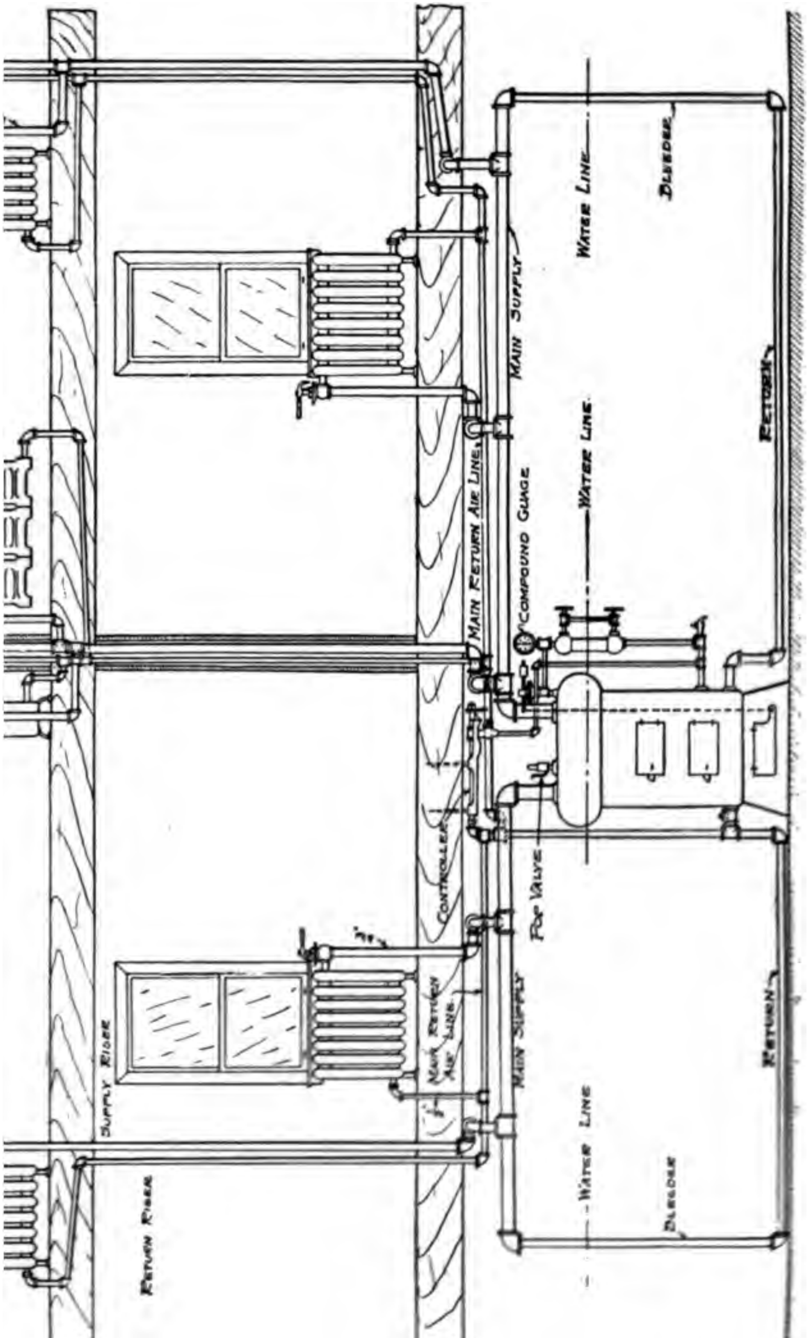


Fig. 125.—Installation of Kriebel System.

with a baffler. The controller allows all air to escape from the system until sufficient heat reaches it to close it by expansion, when the piping system is held under a vacuum. The character of the controller is shown by Fig. 123.

31. **Q. Describe the operation of the Kriebel system.**

A. Shortly after the fire has been started in the boiler, the vapor commences to rise from the water in it and to flow through the main supply pipe into the radiators. As the vapor enters the piping the air is forced ahead of it and discharged from the radiators through the bafflers into the air and return line. From there it is ejected from the system through the controller, the controller at this time acting as a large air valve for the entire system. As soon as the heat enters the brass expansion tube of the controller it expands and closes the exhaust opening; this action closes the system against the pressure of the atmosphere.

The system is now filled with vapor or steam and when the drafts of the boiler are closed the system is placed under a vacuum by reason of the action of the controlling device and all radiators will continue to give off heat as long as there is any vapor present in the system. Immediately more heat is provided at the boiler by opening the drafts, the vapor or steam generated flows uninterrupted through all the piping and radiating surfaces. The system is very simple in operation.

The flow of vapor through a radiator is illustrated by Fig. 124. The vapor enters at the top of one end of the radiator, passes to the opposite end and condenses as it settles toward the bottom of each loop. Fig. 125 illustrates the manner of piping and general method of installing the Kriebel system.

ATMOSPHERIC AND MODULATED SYSTEMS.

1. **Q. What system is known as the "Atmospheric system"?**

A. The Adsco system of the American District Steam Co.

2. **Q. Describe this system and its method of operation.**

A. This system is adapted for use with the one-pipe circuit or regular one-pipe gravity method of piping. It is not a vacuum system as no vacuum principles are applied. It is intended that only so much steam as is required be admitted to each radiator and for this purpose a graduated supply valve is employed and the supply connection is made at the top of one end of each radiator, which should be of the hot water type; the condensation leaves the radiator through a union elbow at the bottom of the opposite end of the radiator and is returned to boiler through a gravity return, where it is connected into a graduated receiver which is open to the atmosphere through a vent line connected into a chimney flue. The condensation passes by gravity from the bottom of the receiver to the boiler.

The system operates without pressure except that of a few ounces at the boiler.

3. **Q. What special appliance controls the operations of the boiler?**

A. A combined damper regulator and relief valve which is extremely sensitive and will operate the drafts of the boiler with a few ounces of pressure. It is connected to the boiler in the same manner as the water bottle of a common diaphragm regulator and will maintain an equal pressure at all times.

4. **Q. What type of boiler is used with this system, and what boiler capacity should be provided?**

A. Any good type of low pressure boiler may be used. The boiler selected should have a low water line so there may be sufficient height in the average cellar or basement from the water line of the boiler to the top of the receiver into which the returns must connect.

The boiler should have at least 50 per cent. more rated capacity than the actual square feet of radiation to be supplied.

5. **Q. What is the character of the receiver into which the returns are connected?**

A. A specially constructed cylindrical shaped casting with

openings at the top for air outlet and return connections and an opening at the bottom for drip or return connections to the boiler. On the receiver is placed a scale graduated in ounces and a water gauge, the glass of which is open to the atmosphere.

6. Q. Can this system be applied to heating installations other than of the character described?

A. This system (by the addition of some special gauges, etc.) may be used on high pressure installations (with reduced pressure) or an apparatus receiving the steam supply from a central plant.

7. Q. What size of piping is required for the Atmospheric system?

A. The following table gives the size of main and return piping recommended for installations of various size:

SIZES OF MAIN AND RETURN—ATMOSPHERIC SYSTEM.

Square Feet of Radiation.	Main Steam Pipe.	Return Pipe.	Length of Pipe of Given Sizes. (See Note.)
50 Feet	¾ Inch	½ Inch	30 Feet
75 "	1 "	¾ "	60 "
125 "	1¼ "	1 "	70 "
200 "	1½ "	1 "	70 "
300 "	2 "	1¼ "	140 "
600 "	2½ "	1¼ "	200 "
900 "	3 "	1½ "	250 "
2,200 "	4 "	2 "	300 "
3,600 "	5 "	2 "	350 "
6,000 "	6 "	2½ "	650 "

Note.—If greater length of pipe is required than is given in the table, use next larger size.

8. Q. What is the Webster modulation system of heating?

A. A two-pipe steam system connected with the ordinary type of low pressure boiler and so installed that a pressure of from 8 ounces to 1½ pounds will furnish all heat necessary. There is no pressure on the return lines as they are vented to the atmosphere and therefore no possibility of water hammer in the piping.

Graduated supply valves are used on the radiators (which should be of the hot water type) the connection being made at the top of the radiator. The return is connected from the bottom of the end opposite to the supply and at this point a special automatic device called a water-seal motor is placed which takes the place of the usual valve or air trap on the return.

ATMOSPHERIC AND MODULATED SYSTEM

9. Q. What method of piping is employed for this system?

A. The method of piping is very much the same as that employed for the regular two-pipe gravity system of steam heating, except that smaller sizes of piping are used. No air valves are used or required with this system.

HEATING GREENHOUSES.

1. **Q. What modern methods are employed for warming greenhouses and conservatories?**

A. Steam and hot water systems are both used; steam at low pressure or hot water, both open tank and pressure systems.

2. **Q. Which system is more generally employed?**

A. Hot water. There are doubtless four or five hot water systems used to one of steam.

3. **Q. What reason can be assigned for this favoring of hot water?**

A. Several conditions contribute to this. Thousands of the smaller greenhouses and conservatories are maintained for the propagation of choice flowers for private use and these are invariably heated with hot water. Steam is used more particularly in commercial houses of large acreage in which hothouse vegetables, fruits or flowers are grown for market sale. Houses of this character have firemen who attend the heating apparatus day and night; on the contrary the heating plant in a smaller or private conservatory seldom has night attendance and for this reason hot water heat is preferred, as should the fire for any reason get low the water continues to circulate and give off heat for hours.

4. **Q. Which type of apparatus is considered to be the best for the propagation of fruit, vegetables, or flowers?**

A. Hot water. The heat from hot water in circulation is mild and the atmosphere in a house heated by hot water is balmy and humid and well adapted to the strong and healthy growth of the plants.

5. **Q. Which is the more economical system to use—steam or hot water?**

A. Hot water is the more economical with regard to the fuel requirements, and a considerable saving in fuel is effected by using hot water in preference to steam. As the cost of heating is the largest single item of the florists' expenses, this fact no doubt has largely to do with their preference for hot water heat.

6. **Q. In what shape are greenhouses usually built, and how are they constructed?**

A. As a rule greenhouses are built long and narrow. Some houses have an aisle two and one-half or three feet wide in the

centre with beds from four to six feet wide on either side. Larger houses have a wide centre bed in addition to those on the sides and consequently have two aisles. The general construction of all commercial houses is similar. They are sided with boarding single or double to the height of the beds; the roof and ends above this line are glass. In low built houses the eaves of the roof begin slightly above the outer edge of the beds. In larger houses there is sometimes a belt of glass between the eaves of the roof and the beds. The pitch of the roof is about one-third to the ridge. Large private conservatories and those in parks and botanical gardens are built in a variety of shapes with all sorts of roof construction, making it necessary to adapt the heating system to the style of construction followed.

7. Q. **How is the radiation required for heating a greenhouse determined?**

A. The amount of glass surface is alone figured in estimating radiation as practically all of the cooling surface is glass.

8. Q. **How can the glass surface in the ordinary greenhouse be quickly determined?**

A. For an approximate estimate, when only the dimensions of the house are given, the glass surface may be considered as equal to the length of the building multiplied by the width plus one-third; the one-third allowance being equal to the ends and the pitch of the roof. Should the greenhouse have a belt of glass on the sides and ends, this additional glass surface should be added.

9. Q. **What temperature must be maintained inside of a greenhouse in zero weather?**

A. The temperature required depends upon the character of the plants or flowers grown. A night temperature is figured on the basis of zero outside and 45 to 55 degrees inside for carnations, 60 to 65 degrees for roses, 55 to 60 degrees for chrysanthemums, etc.

10. Q. **What kind of radiating surface is employed for greenhouse heating?**

A. Pipe coils are used almost exclusively on account of the large area of surface covered by a pipe coil and the more evenly distributed heat.

11. Q. **How is the amount of radiating surface required determined?**

A. For steam to obtain the square feet of heating surface divide glass surface by 7 to obtain a temperature of 50 degrees, 6½ for 55 degrees, 6 for 60 degrees, 5½ for 65 degrees or 5 for 70 degrees.

For hot water use as divisors: 4, 3¾, 3½, 3¼ and 3. This is for zero weather. For climates where there are protracted periods of temperature below zero add 1½ per cent to the radiating surface for each degree below zero. The following tables while not strictly in accordance with the above rules are considered sufficient for average requirements.

FOR STEAM.

Square Feet Glass Exposure.	Number Square Feet Radiation Required at				
	40 Deg.	45 Deg.	50 Deg.	60 Deg.	70 Deg.
100	11	13	14	17	20
200	23	25	30	33	40
300	34	38	43	50	60
400	45	50	57	67	80
500	56	63	72	83	100
1,000	112	125	143	167	200
2,000	223	250	286	333	400
3,000	334	375	429	500	600
4,000	445	500	571	667	800
5,000	556	625	714	833	1,000
10,000	1,112	1,250	1,429	1,667	2,000
20,000	2,223	2,500	2,857	3,333	4,000
30,000	3,334	3,750	4,286	5,000	6,000
40,000	4,445	5,000	5,714	6,667	8,000
50,000	5,556	6,250	7,143	8,333	10,000

FOR WATER.

Square Feet Glass Exposure.	Number Square Feet Radiation Required at				
	40 Deg.	45 Deg.	50 Deg.	60 Deg.	70 Deg.
100	17	20	25	29	33
200	33	40	50	57	67
300	50	60	75	86	100
400	67	80	100	114	133
500	83	100	125	143	167
1,000	167	200	250	286	333
2,000	333	400	500	572	667
3,000	500	600	750	857	1,000
4,000	667	800	1,000	1,143	1,333
5,000	833	1,000	1,250	1,429	1,667
10,000	1,667	2,000	2,500	2,857	3,333
20,000	3,333	4,000	5,000	5,714	6,667
30,000	5,000	6,000	7,500	8,572	10,000
40,000	6,667	8,000	10,000	11,429	13,333
50,000	8,333	10,000	12,500	14,286	16,666

Radiation called for by above table is for tight, well-built houses. For poorly constructed houses add at least 10 per cent.

12. **Q. What boiler capacity is required for this class of heating, and how is the proper size determined?**

A. Greenhouses offer very little resistance to the cold, and therefore require strong boiler power in order to provide quickly for additional warmth to meet the demands of a sudden drop in temperature; therefore ample capacity should be figured. In determining boiler capacity consider 100 square feet of greenhouse coils as equivalent to 125 square feet of cast iron radiation.

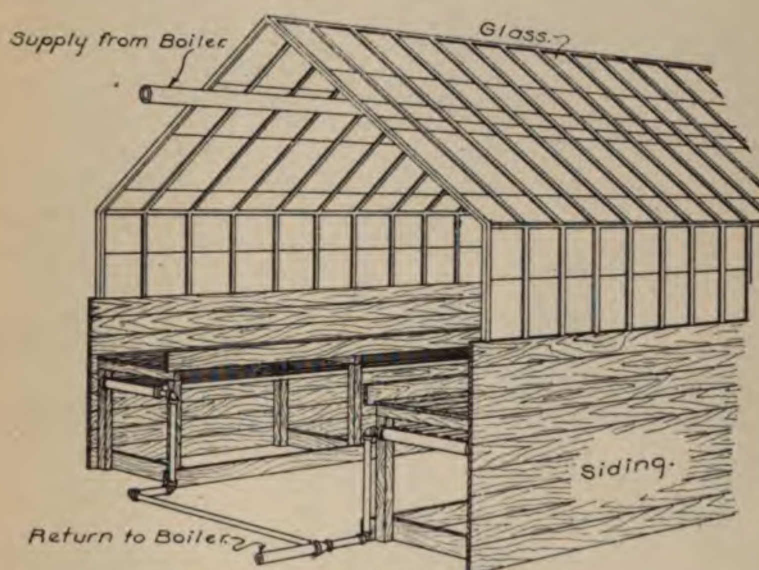


Fig. 126.—Method of Piping a Greenhouse.

Reserve equal to 50 per cent. of the total actual requirements should be provided.

13. **Q. What method of piping is employed in installing a heating apparatus for a greenhouse?**

A. The system commonly called the "overfed system" is most frequently used owing to the benefit derived from a more even distribution of the heating surface.

14. **Q. Describe the overfed system and method of piping.**

A. It is usual for the flow main (or mains—there may be more than one) to enter the house at the end nearest the boiler and to run overhead to the far end of the house, the pipe being hung on

the centre posts supporting the roof. At the far end this pipe is divided, the branches dropping to supply coils usually run under the beds. The flow pitches downward to the far end of the house and the coils pitch downward toward the boiler end; thus there is perfect drainage provided which insures a good circulation. At the boiler end of the house the returns from coils are usually con-

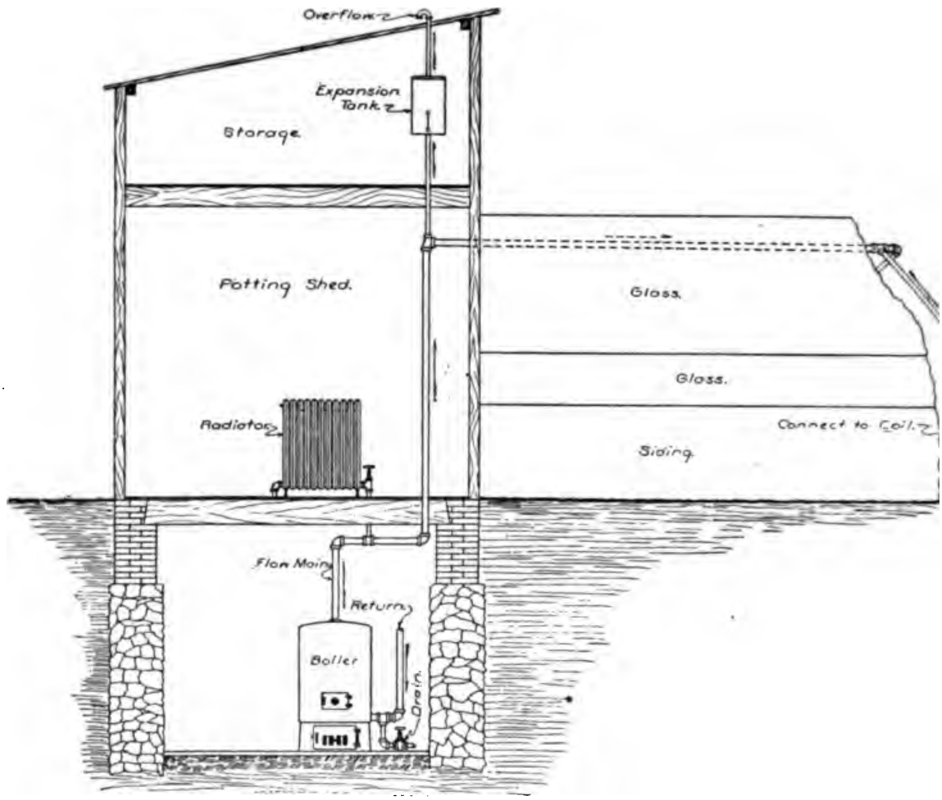


Fig. 127.—Elevation of Greenhouse Piping System.

nected together into a single pipe which leads to the return of the boiler. Fig. 126 illustrates this method.

15. Q. Is there a difference in the method of piping for hot water or steam heating?

A. The general arrangement of the flow and also of the return coils is similar for both systems. If hot water is used the air is exhausted from the system from the high point of the piping through the expansion tank connection at this point.

16. Q. Where is the expansion tank located, and how should it be connected?

A. In building a greenhouse it is usual to erect a potting shed at one end. This portion of the building is usually excavated for a cellar or pit to accommodate the boiler and in many instances has a second floor for use as storage or for the use of the man who attends the heating apparatus. The tank is located in this building well above the high point of the piping and it is connected to the system in the same manner as for the regular overhead system of hot water heating. Fig. 127 shows an elevation of a small house and potting shed.

17. Q. How and where should valves be placed on a heating system for a greenhouse?

A. It is customary to divide the piping into two or more coils according to the size of the house, and each section or unit of radiation should be so valved that a part of the heating surface may be cut out in moderate weather when only a portion of it is required to maintain the desired temperature.

18. Q. Is an accelerated or pressure system adapted to this class of heating?

A. Pressure systems are very commonly employed, a safety valve being used on the outlet of the expansion tank. Accelerated systems may be readily adapted to this work and in the case of exceptionally large plants centrifugal pumps can be employed to advantage.

INFORMATION, RULES, AND TABLES.

The rules, tables and data given on the following pages have been compiled with great care from competent authorities, and the author believes the same to be thoroughly reliable.

For reference the information given will prove of value and service when used in connection with practical experience.

AIR.

Air is an elastic gas composed of 1/5 oxygen and 4/5 nitrogen, and a small amount of carbonic acid gas.

Air expands 1/179 of its bulk. Air may be compressed to liquid form.

One pound of air contains 13,817 cubic feet.

The weight of one cubic foot of air at 32 deg. Fahr. is .080728 pound. At 86 deg. Fahr. a cubic foot of air weighs .07286 pound.

It requires .02056 heat unit to raise the temperature of one cubic foot of air one degree, or 1.4392 heat units to raise the temperature of a cubic foot of air from zero to 70 deg. Fahr.

Theoretically it requires 12 pounds of air to burn 1 pound of coal. Practically 16 to 18 pounds of air may be used.

The pressure of the air (atmospheric pressure) is 14.7 pounds at sea level. The earth is surrounded by a belt of atmosphere something more than forty miles in thickness. The weight of this air presses down upon the earth, exerting an average pressure of 14.7 pounds per square inch.

Air contains more or less moisture (aqueous vapor), the amount varying with the temperature. Air at a temperature of 32 deg. Fahr. can sustain vapor equal to one one hundred and sixtieth (1/160) part of its own weight. At 86 degrees it can sustain one one hundred and fortieth (1/140) part of its own weight.

WATER.

Water is composed of two parts hydrogen and one part oxygen.

Water weighs 62⅓ pounds per cubic foot, or 8⅓ pounds per gallon, and there are 7½ gallons in a cubic foot.

Water is at its greatest density and occupies the least space at 39 deg. Fahr.

Water freezes at 32 deg. Fahr. and boils (at sea level) at 212 degrees. It expands 1/10 of its bulk in freezing and 1/23 of its bulk in boiling.

Water boils at a lower temperature as atmospheric pressure is removed; therefore the higher above sea level the lower the temperature of the boiling point.

Water expands about 1700 times its volume in changing into steam. One cubic inch of water produces one cubic foot of steam.

Water in circulation is the best known absorbent of heat (excepting mercury) and has greater specific heat than any other liquid.

Water in a radiator at a temperature of 180 degrees—temperature of room 70 degrees—emits or gives off to the air 150 B. T. U. per square foot per hour.

The water contained in a cast iron radiator of the ordinary type is approximately one pint for each square foot of radiator surface.

It requires 966 B. T. U. to evaporate 1 pound of water into steam from and at 212 degrees; 34.5 pounds of water evaporated from and at 212 degrees equals one horse-power.

A column of water 27.672 inches high gives a pressure of one pound. A common estimate is one-half pound pressure for each foot in height.

STEAM.

Steam is the vapor arising from water at or above its boiling point, 212 degrees. Steam proper is perfectly transparent and colorless, dry, and wholly invisible except when partly condensed. It is moist only when condensed.

Saturated steam is steam which, in contact with the fluid from which it is formed, carries with it a proportion of its moisture.

Superheated steam is steam heated to a temperature higher than is due to its pressure after leaving the fluid from which it is formed.

The elastic force of steam is equal to the pressure under which it is generated. For example, if generated to a pressure of 50 pounds and freed, its elastic force free will be 50 pounds.

Steam rising from water at its boiling point (212 degrees) has a pressure equal to that of the atmosphere (14.7 pounds per square inch) and at this pressure one pound of steam contains 27.222 cubic feet.

Steam in a radiator at a temperature of 3 to 5 pounds—temperature of the room 70 degrees—emits or gives off to the air of the room 250 B. T. U. per square foot of radiating surface per hour.

FUEL.

Fuel is any substance that can be burned to produce heat. The common varieties of fuel are wood, peat, lignite, coal, gas and oil.

Coal is the principal fuel in the United States and many ot

countries of the world. Coal is ordinarily classified as anthracite and bituminous, or hard and soft coal.

Anthracite is the hardest of all varieties of coal, richest in carbon and greatest in density. Anthracite is almost entirely a product of the State of Pennsylvania.

"True anthracite, when pure, is slow to ignite, conducts heat very badly, burns at a very high temperature, radiates an intense warmth, and is difficult to quench."—*Barr.*

Bituminous coal is a "soft" coal containing a large amount of volatile (gaseous) matter which burns with a smoky flame. It is found in various parts of the United States, the better grades coming from Pennsylvania.

More than 2,000 years ago coal was mined and used in certain parts of the Chinese empire and had been known for years prior to that period.

Virginia coal (bituminous) was mined as early as 1750. Anthracite coal was mined in the Wyoming Valley near Wilkes-Barre in 1768. Coal was mined in the years 1770, 1776, and 1791 in other sections of Pennsylvania.

The calorific values of fuel of various kinds average about as follows:

Anthracite coal, 12,000 to 14,500 B.T.U. per pound.
Bituminous coal, 11,000 to 15,500 " " "
Petroleum (raw), 18,500 to 20,000 " " "
Wood, 2¼ pounds of dry cord wood equals 1 pound of coal.

For low pressure heating purposes, from 5 to 7 pounds of coal per hour are usually considered for each square foot of grate; for high pressure, 12 to 15 pounds per hour for each square foot of grate.

Three tons of anthracite coal per heating season for each 100 square feet of steam radiation and 1½ tons for each 100 square feet of hot water radiation for the heating season is considered a fair average of fuel consumption.

Fifty pounds of anthracite or 40 pounds of soft coal will occupy a space equal to one square foot of grate.

A ton of hard coal occupies space equal to 37 cubic feet; a ton of soft coal occupies 40 cubic feet of space.

MISCELLANEOUS.

Horse-Power.

One horse-power is the power required to raise 33,000 pounds one foot high in one minute; or

The evaporation of 30 pounds of water per hour from a feed water temperature of 100 deg. Fahr. into steam at 70 pounds gauge pressure. This is equivalent to 34½ pounds from and at 212 deg. Fahr.

Tank Capacity.

To find the number of gallons in a round tank multiply the diameter in inches by itself and the result by 0.34.

To find the number of gallons in a rectangular tank determine the cubical contents by multiplying together the length, breadth and height. Multiply this result by 7.48 (the U. S. gallons in one cubic foot).

Mensuration.

Diameter × 3.1416 = Circumference.
Diameter × 0.8862 = Side of an equal square.
Diameter squared × 0.7854 = Area of a circle.
Circumference ÷ 3.1416 = Diameter.
Circumference ÷ 6.28318 = Radius.
Circumference × ¼ the diameter = Area of circle.
Square inches × 0.007 = Square feet.
Cubic inches × 0.00058 = Cubic feet.

Surface in Pipe Coils.

To ascertain the lineal feet of pipe to use when heating by pipe coils, multiply the square feet of radiating surface required as follows:

For	1 -inch	pipe	multiply	radiating	surface	by	0.3
"	1¼-	"	"	"	"	"	2.3
"	1½-	"	"	"	"	"	2.0
"	2 -	"	"	"	"	"	1.6

Blowing Off Boiler.

To remove oil and greasy scum from a boiler it should be blown off under pressure.

Close the valves on supply and returns, or, if none, close all radiator valves. Build a wood fire and generate a pressure of ten or twelve pounds, then open the blow-off valve and draw the fire, open all doors and allow the boiler to thoroughly cool before closing the blow-off cock. When cold refill and build the fire.

Boilers on new work should be blown off two or three times at intervals of two to three weeks. Boilers on old work should be blown off every fall before starting a coal fire.

To Clean a Water Gauge.

To clean the glass gauge on the water column without removing the same, add a teaspoonful of muriatic or other raw acid to a cup of hot water; close both water gauge valves.—Open the draw-off or pet-cock at the bottom and the upper water gauge valve and blow the water out of the glass, then immediately close the top valve and submerge the end of the pet-cock in the acid solution. The vacuum caused in the gauge glass sucks in the solution. By keeping the pet-cock in the solution and alternately opening and closing the upper gauge valve, the solution may be drawn into and expelled from the glass until it is clean. Finally, close the pet-cock and open both gauge valves. There should be one or two pounds of steam pressure on the boiler at the time of the operation.

The Care of a Heating Apparatus.

Proper care of a heating apparatus adds largely to its record of efficiency.

All valves upon a steam job should be left open in the summer when not in use.

Hot water apparatus when unused during the summer should always remain filled with water. This prevents rusting. All doors on the heater should be open and the smoke pipe should be taken down and cleaned and the boiler thoroughly cleaned of ashes and soot.

In the fall before starting a fire the hot water apparatus should be emptied and then refilled with fresh water.

Heating Surface in Tubular Boilers.

To ascertain the heating surface in tubular boilers multiply two-thirds the circumference of the boiler by the length of the same in inches and add to it the outside surface of all the tubes.

Strength of Tubular Boilers.

One-sixth of the tensile strength of plate multiplied by the thickness of the plate and divided by one-half the diameter of the boiler gives a safe working pressure for boilers having single riveted longitudinal seams. For boilers having double riveted seams add 20 per cent.

Chimneys.

The chimney has rightly been called the pulse of the heating system. When called to look at a "sick" job of heating the first

move should be to test out the pulse of the system—the chimney—for here lies 90 per cent. of all trouble.

A study of chimneys and their peculiarities is one of the first requirements of the doctor of heating—otherwise the heating engineer.

Bronzing and Painting.

The work of a heating contractor, in a large measure, is judged by the neatness displayed in finishing a job.

Radiators and exposed piping look best when treated with plain gold or aluminum bronze, the surfaces having first been primed with a coat of flat color, white or light gray if aluminum is to be used, or yellow ochre if gold is selected.

A pound of gold bronze and a quart of liquid will cover 100 feet of direct radiation. Aluminum bronze having more bulk requires about ½ pound for 100 feet of radiation.

TABLE I.

BOILING POINTS OF FLUIDS.

Ammonia	140 deg. Fahr.	Phosphorus	554 deg. Fahr.
Alcohol	173 "	Sulphur	570 "
Benzine	176 "	Sulphuric Acid	590 "
Water	212 "	Linseed Oil	597 "
Sea Water	213 "	Mercury	676 "

TABLE II.

TEMPERATURE OF FIRE.

Approximate—Judged by its Appearance
Table of M. Pouillet.

Appearance of Fire.	*Temperature.*
Red, Just Visible	977 deg. Fahr.
Red, Dull	1290 "
Red, Cherry Dull	1470 "
Red, Cherry Full	1650 "
Red, Cherry Clear	1830 "
Orange, Deep	2010 "
Orange, Clear	2190 "
White Heat	2370 "
White, Bright	2550 "
White, Dazzling	2730 "

TABLE III.

APPROXIMATE MELTING POINTS OF METAL.

Mercury	—39 deg. Fahr.	Silver	1850 deg. Fahr.
Tin	442 "	Brass	1900 "
Bismuth	510 "	Gold	2100 "
Lead	618 "	Copper	1975 "
Zinc	750 "	Cast Iron	2100 "
Aluminum	1150 "	Steel	2532 "
Bronze	1692 "	Wrought Iron	2850 "

Alloy, 3 Lead, 2 Tin, 1 Bismuth	199 "
Alloy, 1½ Tin, 1 Lead	334 "
Alloy, 1 Tin, 1 Lead	466 "

TABLE IV.

AREAS OF CIRCLES.

Size	Area	Size	Area	Size	Area	Size	Area
⅛	0.0123	10	78.54	30	706.86	65	3318.3
¼	0.0491	½	86.59	31	754.76	66	3421.2
⅜	0.1104	11	95.03	32	804.24	67	3525.6
½	0.1963	½	103.86	33	855.30	68	3631.6
⅝	0.3067	12	113.09	34	907.92	69	3739.2
¾	0.4417	½	122.71	35	962.11	70	3848.4
⅞	0.6013	13	132.73	36	1017.8	71	3959.2
1	0.7854	½	143.13	37	1075.2	72	4071.5
⅛	0.9940	14	153.93	38	1134.1	73	4185.3
¼	1.227	½	165.13	39	1194.5	74	4300.8
⅜	1.484	15	176.71	40	1256.6	75	4417.8
½	1.767	½	188.69	41	1320.2	76	4536.4
⅝	2.073	16	201.06	42	1385.4	77	4656.0
¾	2.405	½	213.82	43	1452.2	78	4778.3
⅞	2.761	17	226.98	44	1520.5	79	4901.6
2	3.141	½	240.52	45	1590.4	80	5026.5
¼	3.976	18	254.46	46	1661.9	81	5153.0
½	4.908	½	268.80	47	1734.9	82	5281.0
¾	5.939	19	283.52	48	1809.5	83	5410.6
3	7.068	½	298.64	49	1885.7	84	5541.7
¼	8.295	20	314.16	50	1963.5	85	5674.5
½	9.621	½	330.06	51	2042.8	86	5808.8
¾	11.044	21	346.36	52	2123.7	87	5944.6
4	12.566	½	363.05	53	2206.1	88	6082.1
½	15.904	22	380.13	54	2290.2	89	6221.1
5	19.635	½	397.60	55	2375.8	90	6361.7
½	23.758	23	415.47	56	2463.0	91	6503.8
6	28.274	½	433.73	57	2551.7	92	6647.6
½	33.183	24	452.39	58	2642.0	93	6792.9
7	38.484	½	471.43	59	2733.9	94	6939.7
½	44.178	25	490.87	60	2827.4	95	7088.2
8	50.265	26	530.93	61	2922.4	96	7238.2
½	56.745	27	572.55	62	3019.0	97	7389.8
9	63.617	28	615.75	63	3117.2	98	7542.9
½	70.882	29	660.52	64	3216.9	99	7697.7

TABLE V.

CHIMNEY FLUES.

Steam *Square Feet Rated Boiler Capacity	Water *Square Feet Rated Boiler Capacity	Height of Chimney in Feet.					
		30	40	50	60	80	100
250	375	7.0	....	....	....	....	....
500	750	9.2	8.8	8.2	8.0	....	....
750	1,125	10.8	10.2	9.6	9.3	8.8	8.5
1,000	1,500	12.0	11.4	10.8	10.5	10.0	9.5
1,500	2,250	14.4	13.4	12.8	12.4	11.5	11.2
2,000	3,000	16.3	15.2	14.5	14.0	13.2	12.6
3,000	4,500	18.5	18.2	17.2	16.6	15.8	15.0
4,000	6,000	22.2	20.8	19.6	19.0	17.8	17.0
5,000	7,500	24.6	23.0	21.6	21.0	19.4	18.6
6,000	9,000	26.8	25.0	23.4	22.8	21.2	20.2
7,000	10,500	28.8	27.0	25.5	24.4	23.0	21.6
8,000	12,000	30.6	28.6	26.8	26.0	24.2	23.4
9,000	13,500	32.4	30.4	28.4	27.4	25.6	24.4
10,000	15,000	34.0	32.0	30.0	28.6	27.0	25.4

* Indirect radiation should be made equivalent to direct radiation by adding 50 per cent.

TABLE VI.

PRESSURE IN INCHES OF WATER BY SIPHON DRAFT GAUGE.

Height Water Inches	Pressure per Pound	Velocity Feet per Second	Velocity Feet per Minute	Height Water Inches	Pressure per Pound	Velocity Feet per Second	Velocity Feet per Minute
.1	.521	15.05	903	1.1	5.731	49.9	2994
.15	.781	18.17	1090	1.15	5.991	57.0	3060
.2	1.042	21.3	1278	1.2	6.252	52.1	3126
.25	1.302	23.05	1090	1.25	6.512	53.2	3189
.3	1.563	26.06	1564	1.3	6.773	54.2	3252
.35	1.823	28.08	1685	1.35	7.033	55.3	3315
.4	2.084	30.1	1806	1.4	7.294	56.3	3378
.45	2.344	31.76	1911	1.45	7.554	57.4	3415
.5	2.605	33.6	2016	1.5	7.815	58.2	3492
.55	2.865	35.2	2112	1.55	8.075	59.3	3523
.6	3.126	36.8	2208	1.6	8.336	60.2	3612
.65	3.386	38.3	2298	1.65	8.596	61.3	3666
.7	3.647	39.8	2388	1.7	8.857	62.0	3720
.75	.....	41.2	2469	1.75	9.117	63.1	3774
.8	4.168	42.5	2550	1.8	9.378	63.8	3828
.85	3.907	43.8	2628	1.85	9.638	64.9	3882
.9	4.689	45.1	2706	1.9	9.899	65.6	3936
.95	4.949	46.3	2778	1.95	10.159	66.7	3987
1.0	5.210	47.5	2850	2.0	10.420	67.3	4038

TABLE VII.

AMOUNT OF VACUUM SECURED AT DIFFERENT TEMPERATURES.

Vacuum Gauge Inches of Vacuum	Temperature of Steam or Boiling Point of Water	Vacuum Gauge Inches of Vacuum	Temperature of Steam or Boiling Point of Water.
0 Atmosphere	212 Deg. Fah.	16 Inches	175 Deg. Fah.
1 "	210 " "	17 "	172 " "
2 "	208 " "	18 "	169 " "
3 "	207 " "	19 "	165 " "
4 "	205 " "	20 "	161 " "
5 "	203 " "	21 "	157 " "
6 "	201 " "	22 "	152 " "
7 "	199 " "	23 "	146 " "
8 "	196 " "	24 "	140 " "
9 "	194 " "	25 "	133 " "
10 "	191 " "	26 "	125 " "
11 "	188 " "	27 "	114 " "
12 "	186 " "	28 "	102 " "
13 "	184 " "	29 "	100 " "
14 "	181 " "	29.7 "	98 " "
15 "	178 " "		

TABLE VIII.

VELOCITY OF FLOW OF WATER

In Feet per Minute, Through Pipes of Various Sizes, for Varying Quantities of Flow.

Gals. per Minute	¾ inch	1 inch	1¼ inch	1½ inch	2 inch	2½ inch	3 inch	4 inch
5	218	122½	78½	54½	30½	19½	13½	7⅔
10	436	245	157	109	61	38	27	15⅓
15	653	367½	235½	163½	91½	58½	40½	23
20	872	490	314	218	122	78	54	30⅔
25	1090	612½	392½	272½	152½	97½	67½	38⅓
30		735	451	327	183	117	81	46
35		857½	549½	381½	213½	136½	94½	53⅔
40		980	628	436	244	156	108	61⅓
45		1102½	706½	490½	274½	175½	121½	69
50			785	545	305	195	135	76⅔
75			1177½	817½	457½	292½	202½	115
100				1090	610	380	270	153⅓
125					762½	487½	337½	191⅔
150					915	585	405	230
175					1067½	682½	472½	268⅓
200					1220	780	540	[illegible]

TABLE IX.

B. T. U. REQUIRED FOR HEATING AIR.

This table specifies the quantity of heat in British thermal units required to raise one cubic foot of air through any given temperature interval.

External Temp.	Temperature of Air in Room									
	40°	50°	60°	70°	80°	90°	100°	110°	120°	130°
-40°	1.802	2.027	2.252	2.479	2.703	2.928	3.154	3.379	3.604	3.829
-30°	1.540	1.760	1.980	2.200	2.420	2.640	2.860	3.080	3.300	3.520
-20°	1.290	1.505	1.720	1.935	2.150	2.365	2.580	2.795	3.010	3.225
-10°	1.051	1.262	1.473	1.684	1.892	2.102	2.311	2.522	2.732	2.943
0°	0.822	1.028	1.234	1.439	1.645	1.851	2.056	2.262	2.467	2.673
10°	0.604	0.805	1.007	1.208	1.409	1.611	1.812	2.013	2.215	2.416
20°	0.393	0.590	0.787	0.984	1.181	1.378	1.575	1.771	1.968	2.165
30°	0.192	0.385	0.578	0.770	0.963	1.155	1.345	1.540	1.733	1.925
40°	0.000	0.188	0.376	0.564	0.752	0.940	1.128	1.316	1.504	1.692
50°	0.000	0.000	0.184	0.367	0.551	0.735	0.918	1.102	1.286	1.470
60°	0.000	0.000	0.000	0.179	0.359	0.538	0.718	0.897	1.077	1.256
70°	0.000	0.000	0.000	0.000	0.175	0.350	0.525	0.700	0.875	1.049

TABLE X.

VENTILATION.

Table Showing the Quantity of Air, in Cubic Feet, Discharged per Minute Through a Flue of Which the Cross-Sectional Area is One Square Foot.

(External Temperature of the Air, 32° Fahr.; Allowance for Friction, 50 Per Cent.)

Height of Flue in Feet	Excess of Temperature of Air in Flue above that of External Air							
	10°	15°	20°	25°	30°	50°	100°	150°
1	34	42	48	54	59	76	108	133
5	76	94	109	121	134	167	242	298
10	108	133	153	171	188	242	342	419
15	133	162	188	210	230	297	419	514
20	153	188	217	242	265	342	484	593
25	171	210	242	271	297	383	541	663
30	188	230	265	297	325	419	593	726
35	203	248	286	320	351	453	640	784
40	217	265	306	342	375	484	684	838
45	230	282	325	363	398	514	724	889
50	242	297	342	383	419	541	765	937
60	264	325	373	420	461	594	835	1006
70	286	351	405	465	497	643	900	1115
80	306	375	453	485	530	688	965	1185
90	324	398	460	516	564	727	1027	1225
100	342	420	485	534	594	768	1080	1325
125	383	468	542	604	662	855	1210	1480
150	420	515	596	665	730	942	1330	1630

Above table for Gravity Ventilation taken from standard authorities but not [illegible]anteed.

TABLE XI.

HEAT UNITS IN WATER.

Between 32 and 212 Degrees Fahrenheit, and Weight of Water per Cubic Foot.

Temperature Degrees F.	Heat Units	Weight in Pounds per Cubic Foot	Temperature Degrees F.	Heat Units	Weight in Pounds per Cubic Foot	Temperature Degrees F.	Heat Units	Weight in Pounds per Cubic Foot
32	0.	62.42	123	91.16	61.68	168	136.44	60.81
35	3.	62.42	124	92.17	61.67	169	137.45	60.79
40	8.	62.42	125	93.17	61.65	170	138.45	60.77
45	13.	62.42	126	94.17	61.63	171	139.46	60.75
50	18.	62.41	127	95.18	61.61	172	140.47	60.73
52	20.	62.40	128	96.18	61.60	173	141.48	60.70
54	22.01	62.40	129	97.19	61.58	174	142.49	60.68
56	24.01	62.39	130	98.19	61.56	175	143.50	60.66
58	26.01	62.38	131	99.20	61.54	176	144.51	60.64
60	28.01	62.37	132	100.20	61.52	177	145.52	60.62
62	30.01	62.36	133	101.21	61.51	178	146.52	60.59
64	32.01	62.35	134	102.21	61.49	179	147.53	60.57
66	34.02	62.34	135	103.22	61.47	180	148.54	60.55
68	36.02	62.33	136	104.22	61.45	181	149.55	60.53
70	38.02	62.31	137	105.23	61.43	182	150.56	60.50
72	40.02	62.30	138	106.23	61.41	183	151.57	60.48
74	42.03	62.28	139	107.24	61.39	184	152.58	60.46
76	44.03	62.27	140	108.25	61.37	185	153.59	60.44
78	46.03	62.25	141	109.25	61.36	186	154.60	60.41
80	48.04	62.23	142	110.26	61.34	187	155.61	60.39
82	50.04	62.21	143	111.26	61.32	188	156.62	60.37
84	52.04	62.19	144	112.27	61.30	189	157.63	60.34
86	54.05	62.17	145	113.28	61.28	190	158.64	60.32
88	56.05	62.15	146	114.28	61.26	191	159.65	60.29
90	58.06	62.13	147	115.29	61.24	192	160.67	60.27
92	60.06	62.11	148	116.29	61.22	193	161.68	60.25
94	62.06	62.09	149	117.30	61.20	194	162.69	60.22
96	64.07	62.07	150	118.31	61.18	195	163.70	60.20
98	66.07	62.05	151	119.31	61.16	196	164.71	60.17
100	68.08	62.02	152	120.32	61.14	197	165.72	60.15
102	70.09	62.00	153	121.33	61.12	198	166.73	60.12
104	72.09	61.97	154	122.33	61.10	199	167.74	60.10
106	74.10	61.95	155	123.34	61.08	200	168.75	60.07
108	76.10	61.92	156	124.35	61.06	201	169.77	60.05
110	78.11	61.89	157	125.35	61.04	202	170.78	60.02
112	80.12	61.86	158	126.36	61[illegible]	[illegible]	171.79	60.00
114	82.13	61.83	159	127[illegible]	[illegible]	[illegible]	[illegible]80	59.97
115	83.13	61.82	160	128[illegible]	[illegible]	[illegible]	[illegible]1	59.95
116	84.13	61.80	161	12[illegible]	[illegible]	[illegible]	[illegible]	59.92
117	85.14	61.78	162	1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]9.89
118	86.14	61.77	163	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]87
119	87.15	61.75	164	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
120	88.15	61.74	165	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
121	89.15	61.72	166	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
122	90.16	61.70	167	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE XII.

PROPERTIES OF SATURATED STEAM.

Vacuum, Inches of Mercury	Absolute Pressure, Lbs. per Sq. Inch	Temperature, Fahrenheit	Total Heat above 32° F. In the Water Heat-Units	Total Heat above 32° F. In the Steam Heat-Units	Latent Heat, Heat-Units	Volume, Cu. Ft. in 1 Lb. Of Steam
27.88	1	101.83	69.8	1104.4	1034.6	333.0
25.85	2	126.15	94.0	1115.0	1021.0	173.5
23.81	3	141.52	109.4	1121.6	1012.3	118.5
21.78	4	153.01	120.9	1126.5	1005.7	90.5
19.74	5	162.28	130.1	1130.5	1000.3	73.33
17.70	6	170.06	137.9	1133.7	995.8	61.89
15.67	7	176.85	144.7	1136.5	991.8	53.56
13.63	8	182.86	150.8	1139.0	988.2	47.27
11.60	9	188.27	156.2	1141.1	985 0	42.36
9.56	10	193.22	161.1	1143.1	982.0	38.38
7.52	11	197.75	165.7	1144.9	979.2	35.10
5.49	12	201.96	169.9	1146.5	976.6	32.36
3.45	13	205.87	173.8	1148.0	974.2	30.03
1.42	14	209.55	177.5	1149.4	971.9	28.02
Pounds Steam Gauge.						
	14.70	212	180.0	1150.4	970.4	26.79
0.3	15	213.0	181.0	1150.7	969.7	26.27
1.3	16	216.3	184.4	1152.0	967.6	24.79
2.3	17	219.4	187.5	1153.1	965.6	23.38
3.3	18	222.4	190.5	1154.2	963.7	22.16
4.3	19	225.2	193.4	1155.2	961.8	21.07
5.3	20	228.0	196.1	1156.2	960.0	20.08
6.3	21	230.6	198.8	1157.1	958.3	19.18
7.3	22	233.1	201.3	1158.0	956.7	18.37
8.3	23	235.5	203.8	1158.8	955.1	17.62
9.3	24	237.8	206.1	1159.6	953.5	16.93
10.3	25	240.1	208.4	1160.4	952.0	16.30
11.3	26	242.2	210.6	1161.2	950.6	15.72
12.3	27	244.4	212.7	1161.9	949.2	15.18
13.3	28	246.4	214.8	1162.6	947.8	14.67
14.3	29	248.4	216.8	1163.2	946.4	14.19
15.3	30	250.3	218.8	1163.9	945.1	13.74
16.3	31	252.2	220.7	1164.5	943.8	13.32
17.3	32	254.1	222.6	1165.1	942.5	12.93
18.3	33	255.8	224.4	1165.7	941.3	12.57
19.3	34	257.6	226.2	1166.3	940.1	12.22
20.3	35	259.3	227.9	1166.8	938.9	11.89

TABLE XIII.

NUMBER OF U. S. GALLONS IN TANKS.

Length or Depth in Feet.	Diameter in Inches.															
	18	24	30	36	42	48	54	60	66	72	78	84	90	96	108	120
2	26	47	73	105	144	188	238	294	356	424	497	577	662	750	954	1,178
2½	33	59	90	131	180	235	298	367	445	530	621	721	827	937	1,192	1,472
3	40	71	109	157	216	282	357	440	534	636	745	865	992	1,124	1,430	1,766
3½	47	83	127	183	252	329	416	513	623	742	869	1,009	1,157	1,311	1,668	2,060
4	54	95	145	209	288	376	475	586	712	848	993	1,153	1,322	1,498	1,904	2,354
4½	61	107	163	235	324	423	534	659	801	954	1,117	1,297	1,487	1,685	2,144	2,648
5	68	119	180	261	360	470	593	732	890	1,060	1,241	1,441	1,652	1,872	2,382	2,942
5½	75	131	200	287	396	517	652	805	979	1,166	1,356	1,585	1,817	2,059	2,620	3,236
6	82	143	217	313	432	564	711	878	1,068	1,272	1,489	1,729	1,982	2,246	2,858	3,530
[illegible]½	89	155	235	339	468	611	770	951	1,157	1,378	1,613	1,873	2,147	2,433	3,096	3,824
[illegible]	96	167	253	365	504	658	829	1,024	1,246	1,484	1,737	2,017	2,312	2,620	3,334	4,118
[illegible]	103	179	271	391	540	705	888	1,097	1,335	1,590	1,861	2,161	2,477	2,807	3,572	4,412
[illegible]	110	191	289	417	576	752	947	1,170	1,424	1,696	1,985	2,305	2,642	2,994	3,810	4,706
[illegible]	..	203	307	443	612	799	1,006	1,243	1,513	1,802	2,109	2,449	2,807	3,181	4,048	5,000
[illegible]	..	239	361	521	720	940	1,183	1,462	1,780	2,120	2,481	2,881	3,302	3,742	4,762	5,882
[illegible]	.	287	433	625	864	1,128	1,419	1,754	2,136	2,544	2,977	3,457	3,962	4,490	5,714	7,058
[illegible]	[illegible]	....	....	....	1,008	1,316	1,655	2,046	2,492	2,968	3,473	4,033	4,622	5,238	6,666	8,234
[illegible]	[illegible]	....	....	....	1,152	1,504	1,891	2,338	2,848	3,392	3,969	4,609	5,282	5,986	7,618	9,410
[illegible]	[illegible]	....	....	....	......	......	2,127	2,630	3,204	3,816	4,465	5,185	5,942	6,734	8,570	10,586
[illegible]	[illegible]	....	....	....	......	......	2,363	2,922	3,560	4,240	4,961	5,761	6,602	7,482	9,522	11,762

TABLE XIV.

DIMENSIONS AND CAPACITIES OF STANDARD WROUGHT IRON PIPES.

Nominal Inside Diameter	Actual Diameter, Inches		Area Square In. Inside	Lineal Feet per sq. ft. External Surface.	Nominal wt. Pounds per Lineal Foot	Length of Full Thread	Size of Tap Drill	Gallons of Water per 100 Ft. of Length
	Inside	Outside						
1/8	.27	.41	.06	9.43	.24	.19	21/64	.3
1/4	.36	.54	.10	7.08	.42	.29	29/64	.5
3/8	.49	.68	.19	5.66	.56	.30	19/32	1.0
1/2	.62	.84	.30	4.55	.83	.39	23/32	1.6
3/4	.82	1.05	.53	3.64	1.12	.40	15/16	2.7
1	1.05	1.32	.86	2.90	1.67	.51	1 3/16	4.5
1 1/4	1.38	1.66	1.50	2.30	2.24	.54	1 15/32	7.7
1 1/2	1.61	1.90	2.04	2.01	2.68	.55	1 23/32	10.6
2	2.07	2.38	3.36	1.61	3.61	.58	2 3/16	17.4
2 1/2	2.47	2.88	4.78	1.33	5.74	.89	2 11/16	24.8
3	3.07	3.50	7.38	1.09	7.54	.95	3 5/16	38.4
3 1/2	3.55	4.	9.89	.96	9.	1.	3 13/16	51.3
4	4.03	4.50	12.73	.85	10.67	1.05	4 7/32	66.1
4 1/2	4.51	5.	15.96	.76	12.34	1.10	4 21/32	82.9
5	5.05	5.56	19.99	.69	14.50	1.16	5 15/64	103.8
6	6.07	6.63	28.89	.58	18.76	1.26	6 1/4	150.0
7	7.02	7.63	38.74	.50	23.27	1.36	7 5/16	202.0
8	7.98	8.63	50.02	.44	28.18	1.46	8 5/16	260.0
9	8.94	9.63	62.73	.40	33.70	1.57	9 5/16	326.0
10	10.02	10.75	78.82	.36	40.07	1.68	10 5/16	410.0
11	11.	11.75	95.03	.33	45.00	1.79	11 5/16	495.0
12	12.	12.75	113.09	.30	48.99	1.90	12 5/16	590.0

TABLE XV.

HEATING SURFACE IN WROUGHT PIPE.

Length of Pipe in Feet.	Size of Pipe.									
	¾	1	1¼	1½	2	2½	3	4	5	6
1	.275	.346	.434	.494	.622	.753	.916	1.175	1.455	1.739
2	.5	.7	.9	1.0	1.2	1.5	1.8	2.4	2.9	3.5
3	.8	1.0	1.3	1.5	1.9	2.3	2.7	3.5	4.4	5.2
4	1.1	1.4	1.7	2.0	2.5	3.0	3.6	4.7	5.8	7.0
5	1.4	1.7	2.2	2.4	3.1	3.8	4.6	5.8	7.3	7.7
6	1.6	2.1	2.6	2.9	3.7	4.5	5.5	7.0	8.7	10.5
7	1.9	2.4	3.0	3.4	4.4	5.3	6.4	8.2	10.2	12.1
8	2.2	2.8	3.5	3.9	5.0	6.0	7.3	9.4	11.6	13.9
9	2.5	3.1	3.9	4.4	5.6	6.8	8.2	10.6	13.1	15.7
10	2.7	3.5	4.3	4.9	6.2	7.5	9.1	11.8	14.6	17.4
11	3.0	3.8	4.8	5.4	6.8	8.3	10.0	12.9	16.0	19.1
12	3.3	4.1	5.2	5.9	7.5	9.0	11.0	14.1	17.4	20.9
13	3.6	4.5	5.6	6.4	8.1	9.8	11.9	15.3	18.9	22.6
14	3.8	4.8	6.1	6.9	8.7	10.5	12.8	16.5	20.3	23.4
15	4.1	5.2	6.5	7.4	9.3	11.3	13.7	17.6	21.8	26.1
16	4.4	5.5	6.9	7.9	10.0	12.0	14.6	18.8	23.2	27.8
17	4.7	5.9	7.4	8.4	10.6	12.8	15.5	20.0	24.7	29.5
18	5.0	6.2	7.8	8.9	11.2	13.5	16.5	21.2	26.2	31.3
19	5.2	6.6	8.3	9.4	11.8	14.3	17.4	22.3	27.6	33.1
20	5.5	6.9	8.7	9.9	12.5	15.0	18.3	23.5	29.1	34.8
25	6.9	8.6	10.9	12.3	15.6	18.8	22.9	29.3	36.3	43.5
30	8.3	10.4	13.0	14.8	18.7	22.5	27.5	35.3	43.6	52.1
35	9.6	12.1	15.2	17.3	21.8	26.3	32.0	41.1	50.9	60.8
40	11.0	13.8	17.4	19.8	24.9	30.1	36.6	47.0	58.2	69.5
45	12.4	15.6	19.5	22.2	28.0	33.8	41.2	52.9	65.5	78.2
50	13.8	17.3	21.7	24.7	31.1	37.6	45.8	58.7	72.7	87.0
55	15.2	19.0	23.9	27.1	34.3	41.3	50.4	64.6	80.1	95.6
60	16.6	20.8	26.0	29.6	37.3	45.2	55.0	70.5	87.3	104.3
65	18.0	22.6	28.2	32.1	40.5	48.8	59.5	76.4	94.5	112.9
70	19.4	24.2	30.4	34.6	43.5	52.7	64.1	82.3	101.9	121.7
75	20.7	26.0	32.6	37.1	46.6	56.5	68.7	88.1	[illegible]	[illegible]
80	22.0	27.7	34.7	39.6	49.8	60.2	73.3	94[illegible]	[illegible]	[illegible]
85	23.4	29.4	36.9	42.0	53.4	63.9	77.8	[illegible]	[illegible]	[illegible]
90	24.8	31.1	39.1	44.5	56.0	67.8	82.4	[illegible]	[illegible]	[illegible]
95	26.2	32.9	41.2	46.9	59.6	71.5	87[illegible]	[illegible]	[illegible]	[illegible]
100	27.5	34.6	43.4	49.4	62.2	75.3	9[illegible]	[illegible]	[illegible]	[illegible]

TABLE XVI.

INTERNAL AREAS OF DIFFERENT SIZES AND WEIGHTS OF PIPE.

Diameter in Inches	Internal Areas of Corresponding			
	A Circle	Standard Weight Wrought Pipe	Extra Strong Wrought Pipe	Double Extra Strong Wrought Pipe
1½	1.76	2.04	1.75	.93
2	3.14	3.36	2.93	1.74
2½	4.91	4.78	4.20	2.41
3	7.06	7.39	6.56	4.09
3½	9.62	9.89	8.85	5.79
4	12.56	12.73	11.44	7.72
4½	15.90	15.96	14.38	9.96
5	19.63	19.99	18.19	12.96
6	28.27	28.89	25.97	18.66
7	38.48	38.74	34.47	27.10
8	50.26	50.04	45.66	37.12
9	63.61	62.73	58.42	....
10	78.54	78.84	74.66	....

TABLE XVII.

CAPACITIES AND THREADS OF STANDARD WROUGHT-IRON PIPE.

Nominal Inside Diameter Inches	Length of Thread Inches	Length of Pipe Containing One Gallon—Feet	Contained Lbs. of Water per Lineal Foot	Nominal Inside Diameter Inches	Length of Thread Inches	Length of Pipe Containing One Gallon—Feet	Contained Lbs. of Water per Lineal Foot
⅛	9/32	336.6	.024	4½	1¼	1.2	6.908
¼	⅜	148.8	.044	5	1¼	.96	8.668
⅜	7/16	100.8	.082	6	1⅜	.66	12.521
½	½	63.2	.132	7	1½	.49	16.79
¾	9/16	36.1	.23	8	1⅝	.38	21.688
1	⅝	22.3	.373	9	1⅝	.3	27.58
1¼	11/16	12.8	.648	10	1¾	.24	34.171
1½	13/16	9.4	.883	11		.2	41.189
2	⅞	5.7	1.454	12		.17	49.017
2½	1	4.02	2.072	13		.139	59.762
3	1	2.6	3.202	14		.12	69.125
3½	1 1/16	1.95	4.285	15		.102	81.07
4	1⅛	1.51	5.517	16		.091	91.559

TABLE XVIII.

GALVANIZED SHEET IRON—SIZES AND WEIGHTS.

Gauge	Size	Ounces per Sq. Ft.	Weight of Sheet in Pounds	Gauge	Size	Ounces per Sq. Ft.	Weight of Sheet in Pounds
14	24 x 84	52½	46	23	36 x 84	20½	27
14	26 x 84	52½	49¼	23	40 x 84	20½	20
14	28 x 84	52½	53¾	23	24 x 96	20½	20½
14	30 x 84	52½	57½	23	26 x 96	20½	22¼
16	24 x 84	42½	37	23	28 x 96	20½	24
16	26 x 84	42½	40¼	23	30 x 96	20½	25¾
16	28 x 84	42½	43½	23	32 x 96	20½	27½
16	30 x 84	42½	46½	23	36 x 96	20½	31
16	24 x 96	42½	42⅓	23	40 x 96	20½	34⅓
16	26 x 96	42½	46	23	44 x 96	20½	37¾
16	28 x 96	42½	49¾	24	24 x 84	18½	16¼
16	30 x 96	42½	53	24	26 x 84	18½	17
18	24 x 84	34½	30¼	24	28 x 84	18½	19
18	26 x 84	34½	32	24	30 x 84	18½	20¼
18	28 x 84	34½	35¼	24	32 x 84	18½	22
18	30 x 84	34½	37¾	24	36 x 84	18½	24
18	36 x 84	34½	45¼	24	40 x 84	18½	27
18	24 x 96	34½	34¾	24	24 x 96	18½	18½
18	26 x 96	34½	36½	24	26 x 96	18½	20
18	28 x 96	34½	40⅓	24	28 x 96	18½	21¾
18	30 x 96	34½	42¼	24	30 x 96	18½	23
18	36 x 96	34½	51¾	24	32 x 96	18½	24¾
19	28 x 84	30½	31	24	36 x 96	18½	27¾
20	24 x 84	26½	23	24	40 x 96	18½	31
20	26 x 84	26½	25	24	44 x 96	18½	34
20	28 x 84	26½	27	26	24 x 84	14½	12¾
20	30 x 84	26½	29	26	26 x 84	14½	13¾
20	36 x 84	26½	34¾	26	28 x 84	14½	14¾
20	24 x 96	26½	26⅓	26	30 x 84	14½	16
20	26 x 96	26½	28¾	26	32 x 84	14½	17
20	28 x 96	26½	31	26	36 x 84	14½	19
20	30 x 96	26½	33	26	24 x 96	14½	14¼
20	36 x 96	26½	42	26	26 x 96	14½	15¾
22	24 x 84	22½	19¾	26	28 x 96	14½	17
22	26 x 84	22½	21¼	26	30 x 96	14½	18¼
22	28 x 84	22½	23	26	32 x 96	14½	19½
22	30 x 84	22½	24½	26	36 x 96	14½	21¾
22	36 x 84	22½	29½	28	24 x 84	12½	11
22	40 x 84	22½	33	28	26 x 84	12½	11¾
22	24 x 96	22½	22	28	28 x 84	12½	12¾
22	26 x 96	22½	24¼	28	30 x 84	12½	13¾
22	28 x 96	22½	26⅓	28	32 x 84	12½	14½
22	30 x 96	22½	28	28	36 x 84	12½	16¼
22	36 x 96	22½	33⅔	28	24 x 96	12½	12⅔
22	40 x 96	22½	37¾	28	26 x 96	12½	13½
23	24 x 84	20½	18	28	28 x 96	12½	14⅙
23	26 x 84	20½	19½	28	30 x 96	12½	[illegible]
23	28 x 84	20½	21	28	32 x 96	12½	[illegible]
23	30 x 84	20½	22½	28	36 x 96	12½	[illegible]
23	32 x 84	20½	24				

TABLE XIX.

GALVANIZED SHEET IRON PIPE.

Table of weights of Galvanized Iron Pipe, in pounds per lineal foot.

Diameter of Pipe in Inches.	Number of Gauge.						
	28	26	24	22	20	18	16
6	1.4	1.75	2.0	2.25	3.0	3.75	4.75
7	1.7	2.0	2.25	2.75	3.5	4.5	5.5
8	1.9	2.25	2.75	3.0	4.0	5.25	6.75
9	2.2	2.4	3.0	3.25	4.5	5.75	7.0
10	2.4	2.5	3.25	3.5	4.75	6.25	7.75
11		2.75	3.5	3.75	5.25	6.75	8.25
12		3.0	3.75	4.25	5.75	7.5	9.0
13		3.25	4.0	4.5	6.25	8.0	10.0
14		3.5	4.25	4.75	6.75	8.5	11.0
15		3.75	4.75	5.25	7.25	9.25	12.0
16		4.0	5.0	5.5	7.75	9.75	13.0
17		4.25	5.25	6.0	8.0	10.25	13.75
18		4.5	5.5	6.25	8.5	10.75	14.25
19		4.75	5.75	6.75	9.0	11.5	15.0
20		5.25	6.0	7.0	9.5	12.0	15.5
21		5.5	6.5	7.5	9.75	12.5	16.0
22		5.75	6.75	7.75	10.25	13.25	16.75
23		6.0	7.0	8.25	11.0	14.0	17.5
24		6.5	7.5	8.75	11.5	14.75	18.5
26			7.75	9.25	12.5	15.75	20.0
28			8.5	9.75	13.5	16.75	21.5
30			9.0	10.5	14.0	18.0	23.0

TABLE XX.

DIMENSIONS OF REGISTERS (T. & B.)

Size of opening, Inches	Nominal area of opening, Square Inches	Effective area of opening, Square Inches	Tin Box Size Inches	Extreme dimensions of register face, Inches
6 x 10	60	40	$6\frac{9}{16}$ x $10\frac{9}{16}$	$7\frac{11}{16}$ x $11\frac{11}{16}$
8 x 10	80	53	$8\frac{5}{8}$ x $10\frac{5}{8}$	$9\frac{3}{4}$ x $11\frac{3}{4}$
8 x 12	96	64	$8\frac{5}{8}$ x $12\frac{5}{8}$	$9\frac{3}{4}$ x $13\frac{3}{4}$
8 x 15	120	80	$8\frac{5}{8}$ x $15\frac{5}{8}$	$9\frac{3}{4}$ x $16\frac{11}{16}$
9 x 12	108	72	$9\frac{11}{16}$ x $12\frac{11}{16}$	$10\frac{7}{8}$ x $13\frac{7}{8}$
9 x 14	126	84	$9\frac{11}{16}$ x $14\frac{11}{16}$	$10\frac{7}{8}$ x $15\frac{7}{8}$
10 x 12	120	80	$10\frac{11}{16}$ x $12\frac{11}{16}$	$11\frac{15}{16}$ x $13\frac{15}{16}$
10 x 14	140	93	$10\frac{11}{16}$ x $14\frac{11}{61}$	$11\frac{15}{16}$ x $15\frac{15}{16}$
10 x 16	160	107	$10\frac{11}{16}$ x $16\frac{11}{16}$	$11\frac{15}{16}$ x $17\frac{7}{8}$
12 x 15	180	120	$12\frac{3}{4}$ x $15\frac{3}{4}$	$14\frac{1}{16}$ x 17
12 x 19	228	152	$12\frac{3}{4}$ x $19\frac{3}{4}$	$14\frac{1}{16}$ x 21
14 x 22	308	205	$14\frac{7}{8}$ x $22\frac{7}{8}$	$16\frac{1}{4}$ x $24\frac{1}{4}$
15 x 25	375	250	$15\frac{7}{8}$ x $25\frac{7}{8}$	$17\frac{1}{4}$ x $27\frac{1}{4}$
16 x 20	320	213	$16\frac{7}{8}$ x $20\frac{7}{8}$	$18\frac{5}{16}$ x $22\frac{5}{16}$
16 x 24	384	256	$16\frac{7}{8}$ x $24\frac{7}{8}$	$18\frac{5}{16}$ x $26\frac{5}{16}$
20 x 20	400	267	$20\frac{15}{16}$ x $20\frac{15}{16}$	$22\frac{3}{8}$ x $22\frac{3}{8}$
20 x 24	480	320	$20\frac{15}{16}$ x $24\frac{15}{16}$	$22\frac{3}{8}$ x $26\frac{3}{8}$
20 x 26	520	347	$20\frac{15}{16}$ x $26\frac{15}{16}$	$22\frac{3}{8}$ x $28\frac{3}{8}$
21 x 29	609	403	$21\frac{15}{16}$ x $29\frac{15}{16}$	$23\frac{3}{8}$ x $31\frac{3}{8}$
27 x 27	729	486	$27\frac{15}{16}$ x $27\frac{15}{16}$	$29\frac{3}{8}$ x $29\frac{3}{8}$
27 x 38	1026	684	$27\frac{15}{16}$ x $38\frac{15}{16}$	$29\frac{3}{8}$ x $40\frac{3}{8}$
30 x 30	900	600	$30\frac{15}{16}$ x $30\frac{15}{16}$	$32\frac{3}{8}$ x $32\frac{3}{8}$

Dimensions of different makes of registers vary slightly. The above are for Tuttle & Bailey Mfg. Co.'s manufacture.

TABLE XXI.

SQUARE FEET OF EXPOSED GLASS SURFACE IN WINDOWS OF VARIOUS SIZES.

Width of Window Feet.	HEIGHT OF WINDOW IN FEET												
	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8
1½	3	4	4½	5½	6	7	7½	8½	9	10	10½	11½	12
2	4	5	6	7	8	9	10	11	12	13	14	15	16
2½	5	6½	7½	9	10	11½	12½	14	15	16½	17½	19	20
3	6	7½	9	10½	12	13½	15	16½	18	19½	21	22½	24
3½	7	9	10½	12½	14	16	17½	19½	21	23	24½	26½	28
4	8	10	12	14	16	18	20	22	24	26	28	30	32
4½	9	11½	13½	16	18	20½	22½	25	27	29½	31½	34	36
5	10	12½	15	17½	20	22½	25	27½	30	32½	35	37½	40
5½	11	14	16½	19½	22	25	27½	30½	33	36	38½	41½	44
6	12	15	18	21	24	27	30	33	36	39	42	45	48
6½	13	16½	19½	23	26	29½	32½	36	39	42½	45½	49	52
7	14	17½	21	24½	28	31½	35	38½	42	45½	49	52½	56
7½	15	19	22½	26½	30	34	37½	41½	45	49	52½	56½	60
8	16	20	24	28	32	36	40	44	48	52	56	60	64

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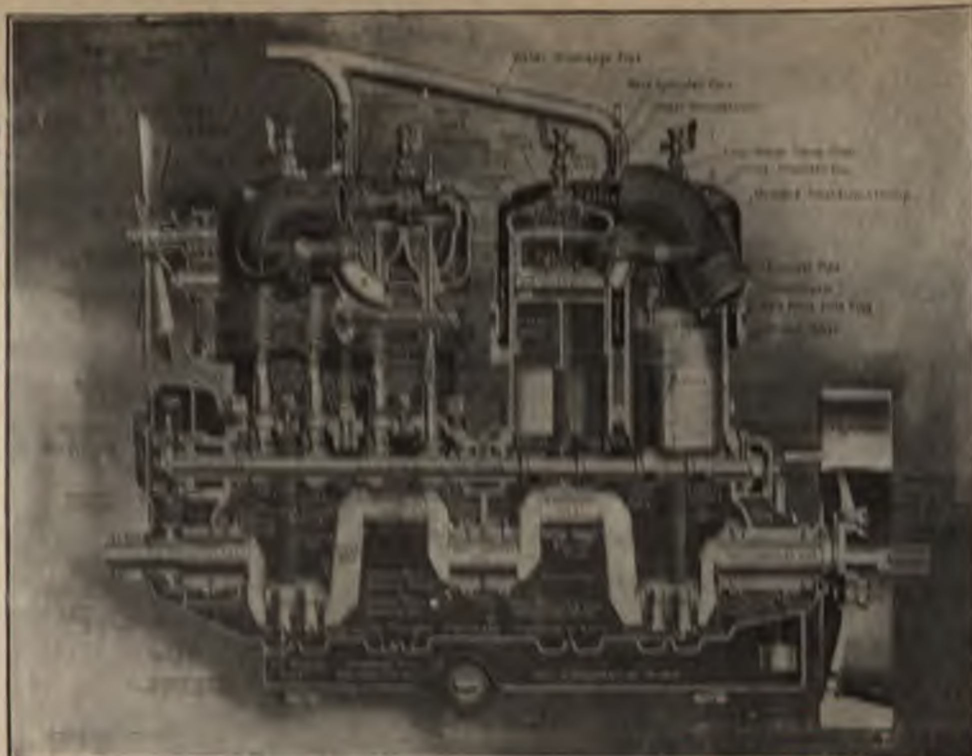

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